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The effect of the Low-emission Zones policy and the Rotterdam Traffic Plan on the usage of alternative modes of transport: The case study of Rotterdam

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Summary

In 2016, Rotterdam was one of the earliest cities to ban the entry of old diesel and petrol passenger cars from its Low emission Zone. By 2020 the city allowed these vehicles back in the zone after it claimed to have reached its targeted reduction in polluting vehicles (Hope, 2019). At the same time, within the Rotterdam Traffic Plan of 2017-2030. The city planned to apply different measures (e.g., Park and Ride, incentives, and infrastructure connections,..). To keep the traffic clean and reduce its intensity while shifting the users' attention towards alternative modes of transport (Rotterdam, G., 2015; Rotterdam, G., 2017). Hence, the main objective of the research is to measure the influence of the "*Low-Emission Zone* policy" and the measures proposed in the *"Rotterdam traffic plan"* on the usage of alternative modes of transport. By alternative modes, public transport, active mobility, and electric mobility are addressed in this research.

The overall aim of this study is to evaluate the role of transport policies in influencing the shifts towards sustainable transportation. To be able to transfer such policies and develop a well-structured lessons-learning, and evaluation framework, this thesis uses a mixed-method approach. It consists of (1) quantitative real-time travel data on transport usage, that mirrors the users' behavior, and (2) qualitative data from in-depth interviews, report and literature that explains the governmental intention as well as justify the users' behavior.

The results proved that the applied transport policies are not significantly affecting the shift towards alternative modes of transport. This mainly occurred because of a gap between the user's awareness and the applied plans and political ambitions. Nevertheless, the data showed a continuous increase in the overall transport users, which is not met by the sufficient provision of sustainable alternatives. The traffic volume in Rotterdam is increasing, and the so-far applied measure from the traffic plan is helping in that increase. However, in the long run, and after the traffic plan is fully implemented (in 2030), the city aims that the traffic might start to be reduced, which is contradicting to the presented status.

To conclude, the research showed that Rotterdam is still moving very slowly towards sustainable mobility and trying to keep holding the stick from the middle, which is not the best strategy to lead such an important transition. The recommendations present a new modified framework (policy package) for cities that wants to start the LEZ to achieve a balanced transport system and prevent conflicts and political issues.

Keywords

Traffic policies, sustainable modes of transport, air pollution, sustainable planning, Paris climate agreement, global emission reduction, climate change, policy transfer, low-emission mobility, contextual differences, User choice, supporting policies, clean mobility, modal shifts.

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Foreword

This study holds a very important and interesting overall aim, which is to evaluate the role of a specific sustainable transport policy (the LEZ) in influencing the users' behavior and their patterns of modal shifts. The idea behind this research came within a long-term personal interest in transport policies and green mobility in developed countries.

Coming from a developing centralized country like Egypt and working in the field of urban development, I have experience with informal transport systems. However, it has always been hard for me to understand how developed countries manage to sustain such a strong and consistent transport system. This research has greatly affected my understanding of the growth of transport policies. It also widened my ideas about green mobility and managing the transition towards sustainable transportation.

Throughout my thesis writing, I was lucky to meet and learn from great experts in the field of transport and mobility. In the beginning, it was difficult to adapt to the Dutch system. However, it got much easier with the support I received from the municipality of Rotterdam, and the different contacts in transport and data collection organization around the Netherlands. Hence, I learned more about data collection, monitoring, and evaluation.

Finally, with what I learned from this thesis and from my overall study in the Netherlands, I can gladly say that I have developed a good set of skills that can qualify me to transfer these skills to my country. However, my passion for learning more is still persistent, and I am looking forward to my next academic steps.

Abbreviations

LEZ	Low-Emission Zone (environmental zone)
RMA	Rotterdam Mobility Agenda
GHG	Greenhouse gases
EV	Electric Vehicles
P+R	Park and Ride system
RET	Rotterdamse Elektrische Tram (Rotterdam main public transport operator)
CBS	Centraal Bureau voor de Statistiek (Central Agency for Statistics)
ANWB	Algemene Nederlandse Wielrijders Bond (Dutch automobile association)
EC	Elementary Carbon
NOx	Nitrogen Oxides
GroenLinks	The Green political party in the Netherlands.
VVD	Volkspartij voor Vrijheid en Democratie (Political party: People's Party for Freedom and Democracy)
TNO	Toegepast Natuurwetenschappelijk Onderzoek (a Dutch private Organisation conducting Applied Scientific Research)
NL times	Netherlands times. Dutch newspapers

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Chapter 1: Introduction

This thesis uses real-time travel-data and vehicle counts to view the influence of the Low-Emission Zones (LEZ) and the Rotterdam Traffic plan on the usage of alternative modes of transport. The aim is to confirm the role of transport policies in influencing the modal-shifts towards sustainable transportation. Moreover, for a policy to be successfully transferred (between different cities), there is a need to identify its influences and explain the conditions that led to its applicability. This will help in linking between user needs and political aims under a contextual framework. This chapter will briefly discuss the background of the problem, the problem statement, and the development of the research questions.

1.1 Background

After the 2016 Paris climate agreement, countries adjusted their long- and short-term plans towards achieving the agreed-upon goals. Air pollution and greenhouse gases (GHG) reduction are among the most highly addressed goals under global action plans. Thus, improving air quality through emission reduction is tackled in policies and municipal plans in most of the European cities (Commission, 2020a; Union, 2015). The transport sector has one of the biggest shares of pollution and emissions worldwide (Edenhofer et al., 2014; International Energy Agency, 2019). Therefore, within the transition towards sustainable cities, policies that promote sustainable transport are being included in both national and local agendas. The Paris agreement has stated different phases for cities to set their agendas on to meet global reduction goals. Accordingly, new transport policies are being phased in, applied, developed, and transferred to different locations.

One of the most important strategies that were being phased-in to different cities worldwide, even before the Paris agreement, is the Low-emission zoning. The idea behind "low-emissions" is to smoothly drive the cities long-run transition towards "zero-emission" (Nagl et al., 2018). The policy was initially applied to freight transport only. Later, after Paris agreement actions, it got transferred to several cities and modified to include passenger cars. Nowadays, cities that succeeded in reducing its dependency on diesel and older vehicles are either leading the shift towards "zero-emissions zones" or phasing-out the policy and replacing it with other restrictions. This shifting decision depends on the achieved air quality level (Commission, 2020b).

However, transferring a certain policy requires paying attention to the contextual differences between cities and systems (Marsden et al., 2011). Also, it is very crucial to consider that “policies should be designed as comprehensive packages rather than as stand-alone measures” (Held and Gerrits, 2019, p.18) (e.g., traffic plans and mobility packages). Currently, more than 250 European cities have Low-emission zones with different packages and contexts (Bannon, 2019). Yet, each of these cities started setting their individual goals to cope with their national agendas. Therefore, a deep understanding of the policy measures within each context is required before transferring any of them to a global practice.

1.2 Problem statement

The LEZ policy measure has proved its global success in improving air quality in many cities. Thus, studies shall be made on the factors that guided this success as well as the factors that were affected by it, “…among the potential effects of the LEZ are changes to the ownership and use of the city’s vehicle fleet, as well as changes to the air quality of the zone” (Ellison et al., 2013, p.4). For transport policies to contribute to the reduction of car usage, it is very crucial to understand the factors affecting the users’ travel behavior (García et al., 2019). In 2017 the number of polluting vehicles in the Netherlands had decreased by 18% compared to 2015 due to the nationally applied Low Emission Zones (LEZ) (NL Times, 2017). Where Rotterdam, the second-largest city in the Netherlands and a base for different modes of transport, was recognized as the most successful city in applying the LEZ at that time (Pieters, 2017; Stratelligence, 2016).

Rotterdam is one of the earliest cities to apply the LEZ for city logistics, since 2007. In 2016 it widened the area of the zone and included a new rule for restricting the old diesel and petrol passenger cars. By 2019, the reduction in the polluting vehicles of Rotterdam reached 99.3% compared to 2015 (Hope, 2019). Thus, while other cities are still struggling to reach the required reduction, from 1 January 2020, Rotterdam stated that it reached the target of the current phase “Traffic in the city is now almost entirely low-emissions” (Hope, 2019, .1). The LEZ initial target was to contribute to a 40% reduction in EC (elementary carbon) and to participate in the decrease of NO2 concentration by 2018, through the total cleans of the inner-city traffic (within the LEZ boundaries).

Therefore, from 2020 old passenger-cars and vans were allowed again in the LEZ while applying other new restrictions (e.g., Parking policies), to make sure that air pollution doesn’t go back to its previous status (Commission, 2020b; Hope, 2019; Rotterdam, M., 2020).

In the case of restriction specific vehicles in transportation policies, governments must offer alternative modes of transport as a replacement. By alternative modes, public transport, active traveling, and electric mobility are addressed. Along the LEZ application in different cities, banned vehicle users, volunteers, and environment enthusiast has filed cases asking for, either removing the policy or providing different alternatives, like improving cycling lanes and boosting electric mobility (2017; Pieters, 2017; Topham, 2020). As mentioned in the NL-Times report, by Mark Aptroot (an environmental volunteer) that, "It must not be allowed that the governments just let things go on as usual after a lawsuit." (Pieters, 2017). Hence, the city must be aware of its duty to provide possible alternatives for these users.

However, the extent of the usage of each transport facility can vary widely based on many conditions (e.g., context, needs, city strategy, etc.). One of the main factors that must have a great influence on the policy is the Rotterdam traffic plan 2017-2030+, which is the current package that includes the LEZ policy measure, among different other measures _Park and ride system, Infrastructure connections and promotional campaigns_. These measures are set to increase awareness, accessibility, and guide the transition towards a sustainable "low emission" future. (Rotterdam, G., 2017). Studying the case of Rotterdam _as a successful city_ will help in explaining those conditions and showing their variation as well as develop a simplified evaluation method to facilitate the same type of transition in other cities.

So far, most of the literature attention is focused on the influence of the LEZ on improving air quality and on logistics fleet. While the least attention is being directed to the influence on the passenger modal choices, modal shift patterns, and the provision of alternatives. "**By comparing the state of transport facilities before and after the policy application and withdrawal, this Masters' thesis aims at explaining and indicating the extent of the influence of Low-Emission Zone policy and the measures proposed in the Rotterdam traffic plan, on the usage of alternative modes of transport. As well as showing the variation in the users' preference and choices for modal share, to be able to manage the demand for transport alternatives before transferring the same policy worldwide**."

1.3 Research objective

The main objective of the research is to measure the influence of the "*Low-Emission Zone* policy" *and the measures proposed in the "Rotterdam traffic plan"* on the demand for alternative modes of transport.

1.4 Research questions

Main Question:

To what extent do the "Low-Emission Zones policy" and the "Rotterdam traffic plan" influence the usage of "alternative modes of transport" in the city of Rotterdam before (2011-2015) and after (2016-2020) the implementation?

- low-emission zone policy: (Concerned vehicles and levels of awareness)
- Rotterdam traffic plan: (Park and ride system, Infrastructure connections and promotional campaigns)
- Alternative modes of transport: (Active travel, Public transport, and Modal-share)

Sub-questions:

- What are the achieved targets of the Low-Emission Zones Policy measure in Rotterdam, and how was it implemented?
- What is the state of usage of Alternative modes of transport in Rotterdam before (2011-2015) and after (2016-2020) the policy adoption?
- How does the low-emission zone policy measure influence the difference in usage of alternative modes of transport before (2011-2015) and after (2016-2020) the policy adoption?
- To what extent do the different measures in the Rotterdam traffic plan influence the user choice of modality before (2013-2016) and after (2017-2020) the implementation?

1.5 Significance of the research

Scientific:

Explaining the link between the application of policies and fulfilling users' demands. So far, the research done on this topic (LEZ policy) is concerned with monitoring its effect on air pollution. This study is concerned with its influence on sustainable modes of transport, as well as on explaining the contextual arrangements and the policy packages (Traffic plan) that led to its acceleration and brought a noticeable progress on air quality. Thus, the research targets a guidance framework to help in transferring the policy to other cities.

Societal:

By studying the influence on modal choices, the research aims at understanding the citizens' behavior based on empirical results, leading to future consideration of their needs. On a larger scale, the research explains a policy that overall targets the improvement of air quality and thus improve health and decrease death rates.

1.6 Scope of the research

This research is a case study focused on Rotterdam. The scope is mainly on the Low Emission Zones, its included vehicles. The research questions the most related measures to the LEZ from the Traffic Plan of 2017-2030+, namely: the park and ride system, the infrastructure connections, and the promotional campaigns. When it comes to the alternative modes of transport, the scale is very wide. Thus, the study is only concerned with the modes for which the municipal has available data, including public transport, cycling statistics, and car ownership, it excludes private companies' services and non-registered vehicles.

1.7 Originality

This topic contributes to filling a gap in the literature on the effect of the LEZ and the current traffic plan on the patterns of modal shifts and transports behavior. Up until today, it is not clear anywhere in the literature, whether the exclusion of older passenger vehicles from the city boundaries is a practical success or a step that shall be taken away. Hence, this research is a novel topic and a leading unique case-study that helps in explaining this specific matter.

The strength of this study comes from its mixed-method approach, which does not only depend on qualitative interviews and governmental intentions but also shows real-time registered data that mirrors the users' behavior. Furthermore, the data is acquired form strong, reliable sources for both, the qualitative (highly specialized and deeply involved set of experts), and the quantitative (Governmental datasets and transport companies real-time counts). Hence, it is a wide-ranging explanatory approach.

Overall, for such a trending policy to be transferred, there must be a lessons-learning and a comprehensive evaluation study done before further application in different cities (Which is what this research if offering).

Chapter 2: Literature review/concepts

This discusses and explores the theories, concepts, and state of the art related to the low-emission zones, traffic plans and the alternative modes of transport. The literature starts with the broader concepts (e.g., Transport policies), then leads towards the specified research variables (e.g., Rotterdam Traffic Plan) and sub-variables (e.g., Park and Ride systems). The description is based on the order of the variables of the main research questions, as will be presented in the conceptual framework (Figure 2.1.).

2.1 Concepts behind the Low Emission Zone

2.1.1 Air Pollution

Reducing air pollution inside cities is one of the pressing issues that are widely addressed globally and locally. Numerous sources cause air pollution and directly affects human health and nature, as well as accelerates the risk of climate change (Kuklinska et al., 2015; Quarmby et al., 2019).

Air pollution is defined by the U.S. Environmental Protection Agency "…as the presence of contaminants or pollutant substances in the air that interfere with human health or welfare or produce other harmful environmental effects" (Vallero, 2014, p.44). Looking into air pollution requires studying the full lifespan of its development and ranges of effect. Thus, it is crucial to have a global benchmark for "Air Quality Standards" to which air pollution must not increase (Vallero, 2014).

Standard Air Quality levels

The target behind standardizing air quality levels and seeking distinct legalizations is to achieve common "healthy" levels. By guaranteeing that the maximum permitted concentration of pollutants _Particulate matter (PM), Ozone (O3), Carbon monoxide (CO), Sulfur dioxide (SO2), Nitrogen dioxide (NO2), Lead (Pb); (Vallero, 2014)_ stays under control without increasing, and by reducing the existing concentration inside cities. Air quality can only be managed if the state of air is monitored to provide periodical "data on the chemical composition or degree of contamination of the air over an area." (Kuklinska et al., 2015, p.1). Based on this, global scientists and world leaders gathered to set clear guidelines for setting international standards for global air quality measures (Vallero, 2014).

2.1.2 International agreements on air quality

The first attention given to air pollution; as a threat that needs fast consideration was in 1960. However, it was not until 1970 that the global "Clean Air Act" created the "National Ambient Air Quality Standards," which are references that indicate the extent to which an area can be identified as harmless or not-polluted. (Vallero, 2014). Nonetheless, the real act of international cooperation towards creating a global agreement started in 1972, and by 1979 the first signed international agreement, "the UNECE Convention on Long-range Transboundary Air Pollution," was established concerning regional-based emission reduction. Later, this agreement was subjected to various modifications, along with the rise of other new international cooperation programs, deals and conventions (Bull et al., 2001; Vallero, 2014).

Paris Climate Agreement (2015)

The most recent global arrangement regarding emission reduction, is the Paris climate agreement of 2015. It directly addresses the reduction of global air temperature and GHG to guarantee sustainable development along different phases of development and through categorizing different types of cities (e.g., Developed cities actions differ from developing ones). All cities shall target the same results "…to maintain the increase in global temperatures well below 2 degrees Celsius above pre-industrial levels, while making efforts to limit the increase to 1.5 degrees." (Erbach, 2016, p.1). As indicated in article 6 of the agreement, cities pursue emission reduction "…to allow for higher ambition in their mitigation and adaptation actions and to promote sustainable development and environmental integrity" (United Nations, 2015, p.746). Therefore, governments are currently addressing emissions reduction in their agendas, including, traffic plans and mobility strategies on both national and local levels, following the agreement's recommendations and timeline.

2.1.3 Policy transfer

Within the growing international agreements (e.g., EU air quality targets), it is common for cities to start copying different successful policies from each other, as they all seek one target under their agreement (Marsden et al., 2011). In Dolowitz and Marsh, 2000; policy transfer was said to be "the process by which knowledge about policies, administrative arrangements, institutions and ideas in one political system (past or present) is used in the development of policies, administrative arrangements, institutions and ideas in another political system." (Dolowitz and Marsh, 2000, p.5). This process is accompanied by different other concepts, such as policy innovations, lesson drawing, and policy diffusion, which might be voluntary actions of transfer or actions pushed by governments to accelerate the development process in a certain direction (Benson and Jordan, 2011). Nevertheless, these transfers lead to changes and modifications in the original policy that was set to be transferred.

Transfers differ nationally or internationally. Since these transfers are greatly affected by the political position and the contextual characteristics of each city, it is required to have a comprehensive understating of the initial position of the city from which the policy will be copied. This comprehensive understanding can offer an opportunity for a more improved and fit policy practices, especially in the field of sustainable transport policies (Marsden and Stead, 2011). Where in places like Europe with the freedom of movement the traffic flow affects different cities at the same time (Scholten et al., 2018) and "…there is a common belief that policy solutions already exist and simply need to be implemented more widely…" (Marsden and Stead, 2011, p.8).

2.1.4 Traffic emissions

The transport sector is responsible for about 25% of GHG emissions, and it is a major reason for air pollution inside cities (European Commission, 2016). Around 90% of European inhabitants are subjected to harmful pollutants, and about 95% of vehicles still run on fossil fuels (Pietrzak and Pietrzak, 2020). Road traffic, which is 93% of transportation share (Mingardo, 2008); is the source of 70% of transport GHG emissions and a large amount of air pollutants. Road traffic forms 39% of nitrogen oxide, and 13% of the particulate matter releases (European Commission, 2016). While the EU's air quality measures have moved towards a better profile in the past years, annual measurements of PM, NO_2, O_3 in several cities still showed an above the safeguard-limit increase in 2016. Remarkably, 100% of the monitoring stations that exposed the increase are traffic based (Tomassetti et al., 2020).

2.1.5 Low-emission mobility

The definition of low-emission mobility varies in the literature. However, it is mostly referred to as mobility that does not contribute to the production of harmful emissions (e.g., active mobility), or that contributes with the least possible effect (e.g., public transport, electric mobility, and shared mobility). (Hulkkonen et al., 2020; Markvica et al., 2017).

In the European Commission (2016)'s report of low-emission mobility, they stated that the solution to all the traffic pollution and emissions' challenges comes from the switch to low-emission mobility in cities. “The ambition is clear: by mid-century, greenhouse gas emissions from transport will need to be at least 60% lower than in 1990 and be firmly on the path towards zero-emission…air pollutants from transport that harm our health need to be drastically reduced without delay.” (European Commission, 2016, p.1).

Low-emission mobility opens the gate for new innovations, technologies, and productions. It provides new job opportunities and introduce creative energy usage, which contributes to the city’s sustainable development. The target can be reached through several layers of approaches including, (1) investing in new technologies for transportation, (2) Increasing public awareness, and (3) introducing policies that prohibit the usage of polluting vehicles (European Commission, 2016).

2.1.6 Low-emission zone policy (LEZ)

Low-emission Zones or “Environmental zones”, are one of the policy approaches to reach the air quality targets for inner cities, within the internationally agreed-upon duration. (Ellison et al., 2013). Low-emissions zones are areas in which the entrance of vehicles that do not apply to a specified emission standard are banned, or highly finned if they enter (Ellison et al., 2013; Fensterer et al., 2014). The policy is implemented in many European cities since its introduction in 1996 in Sweden, over the time and contextual changes, it followed different standards, criteria, and improvements (Stad, G. cited in: Holman et al., 2015). However, “Compared to other types of access restrictions, low-emission zones tend to be simpler to understand and straightforward to implement.” (ACEA, 2015, p.2)

Policy targets

According to the Urban Access Regulations in Europe website (2020), most low-emission zones prohibit busses, coaches, and heavy-duty goods vehicles; while only some of them prohibit vans, minibusses, camper vans, cars, and motorcycles. Most of the cities start by putting a Low-emission city logistics zone, later they add-in the banning of cars and vans as a second phase in their approach.

The policy documents state the restricted vehicles based on the European emission standards grading (Table 2.1.), which is the “…acceptable limits for vehicle exhaust emissions, for new vehicles sold or brought into the EU…” (Ezeah et al., 2015, p.2). Accordingly, European cities varied their policy limitations “With each phase of the process; come stricter measures and minimum emission requirements” (Ezeah et al., 2015, p.3).

Euro Standards	Entry into Force		Emission Limits		
	New Approvals	All New Registrations	Petrol NOx (mg/km)	Diesel NOx (mg/km)	Diesel PM (mg/km)
Euro 0	1 Oct 1991	1 Oct 1993	1,000	1,600	(no limit)
Euro 1	1 July 1992	31 Dec 1992	490	780	140
Euro 2	1 Jan 1996	1 Jan 1997	250	730	100
Euro 3	1 Jan 2000	1 Jan 2001	150	500	50
Euro 4	1 Jan 2005	1 Jan 2006	80	250	25
Euro 5	1 Sep 2009	1 Jan 2011	60	180	5
Euro 6	1 Sep 2014	1 Sep 2015	60	80	5

Table 2-1 : Euro standards for NOx and PM emissions, by age of the vehicle (Ezeah et al., 2015, p.2)

LEZ development in Rotterdam:

The first low-emissions zone in Rotterdam started in 2007, which banned only freight transport of euro 3 and lower. In 2016, it started banning passenger cars and vans of euro 3 and lower. Fortunately, in 2020 the city had reached its target for polluting vehicle reduction. Thus, it allowed passenger cars and vans again, while kept banning the lorries and heavy-duty goods vehicles (European Commission, 2020; Green Zones, 2020; Hope, 2019).

Implementation

Governments are applying different measures for reducing car usage (e.g., congestion charges, taxation, incentives, and developing public transport.) (Wright and Egan, 2000). These measures can be called “Hard or structural” measures that work strategically on pushing people away from a certain habit and pulling them towards another. However, while “structural” measures might have a great influence on changing the users’ travel behavior, sometimes commuters prefer to pay the fine, or refuse to follow the rule based on their trip characteristics and personal choices. Therefore, governments must work as well on the “Soft or Psychological” measures which target increasing the individuals’ environmental awareness (e.g., offering education about car-driven pollution, and raising the knowledge for the presence of alternatives) (Eriksson et al., 2006; Loukopoulos et al., 2004; Vlek, 1996).

Overall, reducing the car usage is a two-way action that shall be powered through top-down (policies and alternatives), and bottom-up (awareness and willingness) approaches, where the user acceptance of change is the main driving-force (Loukopoulos et al., 2004)

2.2 Concepts behind the Rotterdam Traffic Plan

2.2.1 Transport policies

Transport managing and decision-making is a very complex and challenging task (Geerlings et al., 2012, p.5; Givoni, 2014). Transport policies are basically described as policies and induced measures that deal with transport problems (Wang, 2010).

The success of future cities lies under creating a city where users no longer need to use their cars. Instead, they will have affordability, proximity, health, and open spaces. It is important that governments incorporate strategies to promote sustainable mobility that provides a new transport hierarchy, which focuses on the social dimension, accessibility, modal shifts, open spaces, and integration of people with traffic (Banister, 2008).

2.2.2 Transport policy-packages

The effect of stand-alone policies is limited, and sometimes they produce many unwanted side effects (Givoni, 2014). Policies shall be accompanied by a set of measures and be included in a package to complete the development process (Mingardo, 2008). Policy packages are "a combination of policy measures designed to address one or more policy objectives, created to improve the effectiveness of the individual policy measures, and implemented while minimizing possible unintended effects…to increase efficiency" (Givoni et al., 2013, p.3). Yet, it is still considered a vague and fluctuating concept, with different practices and understandings (Givoni, 2014).

Within the different measures that guide the shift towards sustainable transportation, some measures are preferred and proved more successful than others. For instance, European research showed that improving the public transport and the park-and-ride systems are preferred by about 90% of the car users. In contrast, only 20% of car users agreed on the cordon pricing and parking spaces reduction (Eriksson et al., 2006; Schlag and Schade, 2000). Therefore, it is important to understand the context of each city before including any measurements in the policy or plan.

Rotterdam Traffic Plan 2017-2030+

As a transport policy package, the Rotterdam Urban Traffic Plan is a plan that has short- and long-term actions, measures, and initiatives that contribute to an overall goal, which is a "Smart, accessible, healthy, economically strong, and attractive city". This goal is approached through integrative mobility planning falling under both, the city 2030 vision, and the mobility agenda. In the introduction of Rotterdam's Urban Traffic Plan 2017- 2030+, the author declared mobility as "…not a goal in itself, but is instead an essential precondition for an attractive and economically strong city…" (Gemeente Rotterdam, 2017, p.7).

The document introduces these nine main policy decisions: "(1) Fewer car kilometers within the Ring (2) An interconnected regional and urban network (3) Regional and urban river crossings (4) An appealing and vibrant city and center (5) Boosting new modes of transport (6) Eliminating transport poverty (7) A healthy living environment (8) Smart mobility (9) Areas outside of the Ring. " Under each of these decisions comes a set of actions (e.g., Park-and-ride system, Infrastructure connections, and promotional campaigns) that the municipality will follow to reach the target. (Rotterdam, G., 2017, p.9)

Infrastructure connections

"The development of transport infrastructure has direct implications for spatial accessibility at both the national and regional scales." (Hou and Li, 2011, p.1) Improving infrastructure connections include increasing accessibility by increasing the length of internal and external rail-lines, upgrading last-mile distances, and providing new modes of transport to reach different locations. Moreover, the increase in connections decrease the overall travel time and trip lengths, which act in favor of the user choices for transport facility. Finally, studies showed that upgrading bike and bus infrastructure could have a positive impact on decreasing the CO_2 emissions (Hou and Li, 2011; Jain and Tiwari, 2016).

Therefore, Infrastructure connections are the main concern in the Rotterdam Traffic Plan. They are starting from connecting the regional and urban traffic through road extensions, river crossings, smart mobility, last-mile connections, and providing new modes of transport (Rotterdam, G., 2017).

Promotional campaigns

Environmental awareness measures can be addressed through promotional campaigns and advertisement propagandas. Where it either targets the individual's "sense of public duty" or their sense of "self-image" (Wright and Egan, 2000). According to the "Value-Belief-Norm" theory, a personal norm of daily actions can be activated through tackling his values and beliefs (e.g., valuing the environmental problem and believing in its harmful consequences, leads to the personal willingness to act pro-environmentally) (Eriksson et al., 2006).

Therefore, awareness measures are addressed in the Rotterdam Traffic Plan under the "Eliminating transport poverty" decisions. Where knowledge is increased through launching initiatives, providing mobility options to diverse groups, encouraging participation and social activities within the car-free city center environment (Rotterdam, G., 2017).

<u>Park-and-ride systems (P+R):</u>

"P+R is a service provided to motorists to park at (usually) the periphery of an urban area, where public transport operates to and from the city center. Park and Ride (P+R) facilities are introduced as a key element of the sustainability packages of many urban areas in Europe." On the one hand, governments are providing parking spots for the escalating number of cars; on the other hand, they are pushing the car usage outside of the city and increasing the demand for internal public transport (Dijk and Montalvo, 2011, p.1). There are different types of P+R, based on the land-use division. It either targets catching the drivers from (1) locations near their houses in suburban areas, or (2) in peripheral areas, before reaching their destinations or finally (3) along (in-between) their trip (Mingardo, 2013).

Rotterdam P+R has a mixed target group; it targets both external drivers before entering the city and local commuters before going outside (Mingardo, 2013). In the Rotterdam Traffic Plan, P+R stations are served under the decision of "providing an interconnected regional and urban network" and the "appealing and vibrant city and center." Where new P+R locations are introduced, and road connections are to be made serving all the P+R locations that surround the city, addressing the regional based traffic and freeing the internal city spaces (Rotterdam, G., 2017).

Generally, the traffic plan aims at achieving a balance between all modes of transport, biking, walking, private cars, and public transport, and targets spatial and economic development by improving accessibility, livability, and increasing densification (Rotterdam, G., 2017).

2.3 Concepts behind the Alternative modes of transport

2.3.1 Modal shifts and patterns of users' choices

Modal shifts mean the switch of usage from one mode to another, leading to a change in the overall mobility structure (e.g., using public transport instead of cars) (Cuenot et al., 2012). Several patterns are linked to the concept of modal shift and its application. It is crucial to identify each pattern and study its effects and range of users before any decision-making.

Modal shifts can be led through changes in the external built environment, transport quality, availability, induced policies and promoted campaign (Loukopoulos et al., 2004; Scheiner et al., 2016). Some changes lead to full modal shifts, while others are a half-shift that can be a step towards full shift later. It is crucial for policymakers "to know whether interventions promoting sustainable transport modes can produce long-term changes" (Chatterjee et al., 2016, p.1) or not. A profound understanding of modal choices and potential shifts can guarantee a better prediction of the associated impacts, like air pollution and traffic congestion. Thus, it can provide a knowledge-base for future planning (Heinen et al., 2017). Overall, to achieve sustainable transport by modal shifts, it is essential to work on different tracks, based on future needs, contextual changes (Doi and Kii, 2012), and supply of sufficient alternatives.

2.3.2 Sustainable transport

Sustainable transport is "transportation services that reflect the full social and environmental costs of their provision; that respect carrying capacity; and balances the needs for mobility and safety with the needs for access, environmental quality, and neighborhood livability" (Jordan and Horan, 1997, Cited in: Jabareen, 2006, p.3). From this, sustainable transport can include electric mobility, public transport, and active traveling. Shifting to sustainable transportation means facing three main challenges: (1) overcoming the reliance on private cars, (2) providing zero-emission alternatives, and (3) adapting the public attitudes. This implies high measures of innovation, management and modal shifts (Doi and Kii, 2012). This shift can be led through changing policy measures, encouraging innovation, and increasing awareness, based on scientific knowledge along with trial and error approaches.

2.3.3 Alternative modes of Transport

The term "alternative modes of transport" in literature is very wide; every study includes the modes that are most relevant to its approach. To begin with, Stradling (2011) classified modes of transport into three main forms: (1) Self-boosted modes, e.g., walking; (2) supplemented modes, e.g., cycling; and (3) Powered modes, e.g., vehicles.

In some literature, alternative modes of transport are classified through dividing modes of transport into; traditional, transitional, and sustainable. This division describes modes of transport by the extent to which they are harmful to the environment. In other literature, "alternative modes of transport" are mentioned when describing "Sustainable transport" or "Public transport" (Stradling, 2011). For this thesis, the alternative modes of transport will include "Active travel," "public transport," and "electric mobility."

Active travel

Active travel is any sort of travel that requires physical activity from the traveler to reach his destination, specifically cycling and walking (for function rather than leisure). The description varies in literature for stating the duration and the repetition of a trip that allows it to be called "active travel". However, it mainly ranges between 20 to 30 or more minutes of travel per day (Saunders et al., 2013).

Policies that promote active travel can contribute to substantial health improvement as well as a reduction in pollution levels and GHG. The call for increasing active travel within a city can be direct; through promotional campaigns and awareness, or indirect; through improving infrastructure and supporting the car-use reduction (De Nazelle et al., 2011).

Public transport

The definition of "Public transport" in most literature is varying and vague. This is because the concept raises different questions on what is included and what is not. However, the most common definition is "transport services made available to the general public", which are to a great extend "provided or controlled by governments". However, the definition sometimes includes the private-sector based facilities that serve the public (Glover, 2011, p.2).

The provision of public transport is always associated with sustainable development due to its role in supporting both the social and environmental pillars of sustainability (Buehler and Pucher, 2011). On the social level, "for most of the population of cities, public transport is the only means to access employment, education and public services." (Metrobus, 2013 cited in: Paget-Seekins and Tironi, 2016). While on the environmental level, improving public transport facilities and increasing its usage instead of private cars has proved a major influence on the reduction of pollution and emissions (Jain and Tiwari, 2016).

Electric mobility

Electric mobility is defined as "…mobilities involving electric vehicles, i.e., vehicles that rely on an electric motor for at least some of their propulsion with the power coming from an on-board battery (e.g., car or bike) or an off-vehicle source (e.g., train)…" (Behrendt, 2018, p.3).

Automated traffic in the twenty-first century is an inevitable human need. As long as our societies are depending on private vehicles and road traffic for their daily need, governments must act towards the reduction of the severe environmental risks that comes within that traffic (Mattioli et al., 2020; Sovacool, 2017). Hence, electric mobility is introduced to solve this problem and act in favor of the future air quality levels. Electric mobility is considered the best out of the current travel options to reduce the traffic carbon footprint (Kollosche, 2014).

Governments are introducing different policies and practices that promote the replacement of convenient mobility (Diesel, petrol...) by electric mobility. Among these policies, the fiscal incentives, prioritizations, infrastructure provision, and the banning of conventional cars are the most successful. (Held and Gerrits, 2019). In that sense, e-mobility is a major aspect to be discussed in this thesis as a stand-by solution and a parallel framework for the city to be working on.

Modal Share

Modal share is a term that describes the share of usage for each transport facility within a unit of study. Some public transport users prefer to mix between different modes of transport (Modal mixes: motorized and non-motorized) within the same trip, which creates a variation in the overall modal shares and demands (Heinen et al., 2017). Modal shares can also be a result of "multimodality," which is "is defined as the use of at least two modes of transportation _bicycle, car, or public transportation_ in 1 week." (Nobis, 2007, p.1).

Modal share is subjective. It depends on the trip characteristics, personal choices, and transport availability. Thus, it is important to recognize the public demand on each mode within each city or context, to have accurate development strategies (Scheiner et al., 2016).

2.4 Conceptual Framework

From the above-described concepts, this thesis is more linked to concepts of *Low-emission mobility*, *transport policies,* and *sustainable transport*. Figure 2.1. illustrates the conceptual framework of this thesis where *Low-emission zones policy* (Independent Variable), the *Rotterdam traffic plan* (Independent Variable), and the *alternative modes of transport* (dependent variable) are respectively the derived subjects of these concepts.

Furthermore, the Figure shows the breakdown of variables into sub-variables and then indicate some of the main research indicators, which will be viewed in detail in the operationalization table (Chapter 3, Table 3.1.).

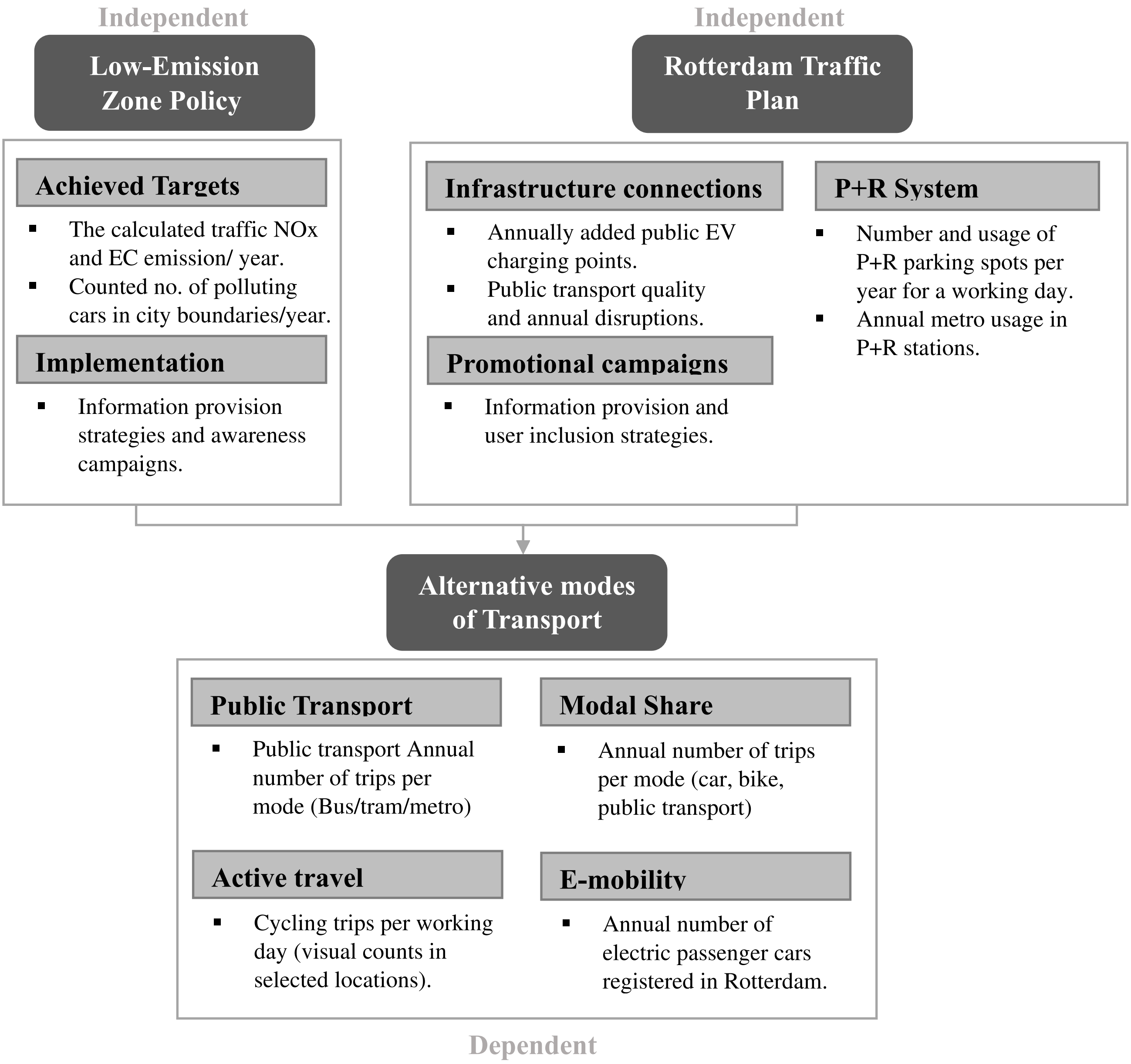


Figure 2.1: Conceptual Framework (Variables- Sub variables and Main indicators)

Chapter 3: Research design, methods, and limitations

3.1 Introduction

This chapter describes the research methodology and data analysis framework through three main sections. The first section includes the research design and methods describing the type and strategy of the research, data collection methods, and research instruments, including the sampling techniques, then discusses the quality criteria. The second section includes the data analysis, which describes the methods of data, analysis, organization, and display. Then the final section includes the operationalization through describing the main research variables definitions and then the table of selected indicators.

Figure 3.1. illustrates the methodology and framework of the research and the sequence of data collection, which will be described in this chapter.

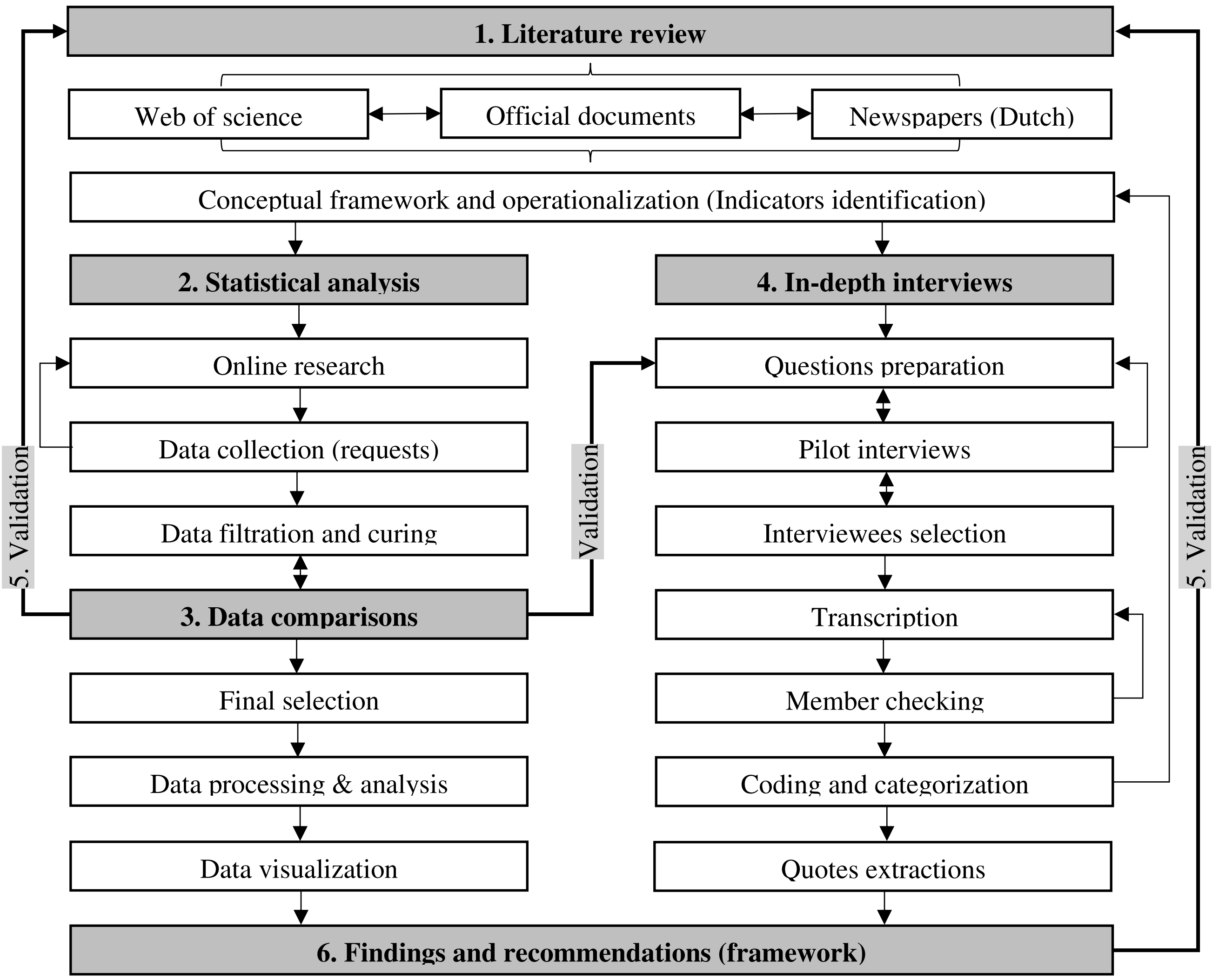


Figure 3.1 Methodology and research framework

3.2 Research Design and methods

3.2.1 Research type and strategy

Type:

This research adopts an explanatory deductive approach; it aims at the deep explanation of the extent to which a certain transport policy measure and its package influences the users' choices for transport modes. It also targets the explanation of the difference in the users' choices and modal shares.

Strategy:

This research is focused only on explaining the Low-emission Zones and the Rotterdam Urban traffic plan and their effect on the transport patterns for the same city. Thus, the strategy is a **single case study**, which indicates real-life special example, that is unique and specific in its context, implying results that are only valid for that context (Van Thiel, 2014).

3.2.2 Data Collection methods

An adequate data collection method for this research scope and population is a "**mixed method,"** specifically triangulation design. The choice for this method is due to the doubt in sources reliability and the variation of measurement methods. Hence the mixed method is selected "to validate or expand quantitative results with qualitative data." (Creswell, 2006, p.62) and to make sure that the information is agreed upon, in 3 different sources.

The research is addressed through **(1) qualitative approach** for the literature reviews, from the web of science, official documents, and Dutch newspapers. This textual approach helped to identify the main variables and indicators as well as to back-up and validate the other two sources of data. The second dataset was addressed through the **(2) quantitative approach**, which included the existing statistical data from the municipality portals and the transport companies. The statistical data is either already calculated or needed some analytical processing (see Chapter 4). Finally, these datasets were triangulated through a **(3) qualitative approach,** namely by conducting in-depth interviews with officials and experts from the field. This final dataset acted as a source for filling the gap in research, especially to develop subjective results on the governments' motives, and residents' patterns in Rotterdam.

3.2.3 Research Instruments

Literature review and statistical data:

This thesis is comparing the usage of alternative modes of transport before and after the policy application. Thus, it is considered a "study overtime" or a year to year comparison. For this type of studies it is best to perform a secondary data analysis to get the archived data; **(1) from secondary sources;** through literature review, reports, and documents, and **(2) from primary sources;** through already existing statistics and real-time registrations. Thus, those together are approached through meta-analysis, producing a new outcome, compared to the main reasons they were gathered for. (Van Thiel, 2014).

In-depth interviews:

in case study research to increase the validity of the secondary data collected, it is adequate to use interviews as a source **(3) for primary data**. In this research, semi-structured interviews were conducted with experts, key informants, and policy officials from Rotterdam and European cities. The questions in the interviews (see Annex 1), are based on the indicators and are following the main research variables, in order to validate and triangulate the results found through the collected secondary data (Bogner et al., 2009; Van Thiel, 2014).

3.2.4 Sampling design

The whole population of transport users is addressed through the real-time passenger primary data. Where, three types of sampling are done.

For literature review:

The selected literature focused on the development of traffic and air quality policies in Rotterdam (official documents), international agreements, and similar policies worldwide (web of science). Finally, to collect more details on the case of Rotterdam, and to get more local evidence on the problem, articles on the LEZ and the traffic plans in Rotterdam was searched in different trusted newspapers (Dutch newspapers). Overall, the research focus on specific keywords (e.g., LEZ, Environmental zones, Polluting vehicles…).

For the statistical data:

the sampling selection focused on specific transport indicators (e.g., car counting, public transport trips), through investigating all reliable data suppliers and web portals (e.g., RET reports, municipality documents, published research on Rotterdam) to gather information through stratified desk research and coding.

For the in-depth interviews:

non-probability sampling is done through purposive selection of the related officials and transports' responsible by choosing a selective and rational number of respondents to cover the concerned organizations. The larger the sample, the better. For this research, the number of semi-structured interviews shall be between 6 to 10 since the purpose of semi-structured interviews is only for triangulation (Van Thiel, 2014).

Hence, in addition to some e-mail based discussions with some transport companies researchers (e.g., (Translink, 2020), (RET, 2020), (CBS, 2020), ...), the final sample of interviewees included seven main respondents (See chapter 4, 4.3. for more information).

3.2.5 List of respondents and sources

Different companies and experts were approached through the data collection period. Out of 25 approached data collection company and/or private contact, as well as 20 different experts for the interviews, the following are the final sources:

For the literature review and the statistical data

- Online sources: (1) Municipality of Rotterdam portal (Rotterdam, G., 2020), (2) RET annual reports (RET, 2020), (3) Published academic research on Rotterdam (Geerlings et al., 2020; Mingardo, 2013), and (4) Newspaper articles (e.g., NL-times, AutoBlog, AutoWeek).
- Offline sources: (1) Datasets received from the municipality mobility department (2) Datasets received from the RET research department, (3) Granted permanent access to digital research resources for the OViN datasets of the CBS (CBS, 2020; DANS, 2020), and (4) Document received from the TNO independent research organization (TNO, 2020)

For the in-depth interviews

- The municipality: the municipality decision-makers are a major player in this research. Thus, the main respondents for the interviews included (1) LEZ decision-maker, and (2) Traffic Plan decision-maker.
- Mobility experts: two types of experts were included (1) Experts from Rotterdam who were involved in the policies decision making, (2) experts from different European cities that

applied the LEZ or have strict successful traffic plans (For the sake of exploring different contexts and possibilities for the policy transfer)

- Transport companies: It was difficult to set an interview with researchers from companies like the RET, as they do not offer that for students, especially due to COVID-19 circumstances. However, some major points were discussed through e-mails, and they shared their available data sources instead.

For details on the interview's respondents and their fields of expertise, (see chapter 4, 4.3.)

3.2.6 Quality Criteria

External Validity:

The research is characterized by being unique research and having a new approach that opens the gate for new further investigations in that matter and helps in achieving comprehensive results that benefits the whole population sample. However, case studies cannot be generalized. Therefore, the external validity is considered weak. Therefore, interviews and literature reviews from different contexts and cities are used for supporting the argument.

Internal Validity:

The research focuses only on specific variables to increase the validity, while triangulating the statistical information through semi-structured interviews, reports, and literature reviews. Furthermore, the research follows and compares previously done research on similar topics.

Reliability:

To ensure the reliability of the research: the sampling selection is very reasonable, and based on the involved officials, major researchers, and specific data sources. The research ensures the accuracy of respondents and consistency through member checking, peer examination, and memo logs. While for the datasets, getting the same information from more than one source and triangulation and recalculating results is applied.

3.3 Data analysis

As mentioned above, the research methodology used in this thesis is mixed methods; it relies equally on the three sources, literature review, real-time statistical data, and the semi-structured interviews. The main purpose of this method is to ensure, validate, and triangulate the information in a comprehensive manner that fill in the information gap.

3.3.1 Methods of clustering and organizing the data

The research followed a meta-analysis approach where different data sources and types are used and analyzed, aiming at a comprehensive result. This section describes the research methodology steps of organization and analysis, as viewed in Figure 3.1.

Literature review:

Literature, official documents, and newspaper articles were used as (1) a start for the research identification, (2) a continuous checking reference, and finally as (3) a source for results validation. The literature data is analyzed using manual coding and categorization. At the same time, the maps and photos are analyzed visually through presentation software (e.g., Adobe Photoshop CC, Microsoft PowerPoint).

First, the literature focused on all the previous research done in Rotterdam, specifically. However, due to the sensitivity and the newness of the approach, it was difficult to find related research for Rotterdam. Thus, mainly documents from the municipality evaluation reports and the local newspaper was used for the case of Rotterdam. Along with some specific research done on air quality policies and P+R usage (Geerlings et al., 2020; Mingardo, 2013).

Furthermore, other literature was used in similar contexts, either in European cities that applied the researched policies or in cities that have a similar context to Rotterdam (e.g., Harbour, Car-based cities) to have an overall idea of the different application of the policies worldwide.

Statistical data:

The statistical data is used to collect an over-time dataset (annual registration/ vehicle counts) for the past ten years. The data is analyzed and visualized using different professional analysis tools (Microsoft Excel 365 charts, and IBM SPSS Statistics 25).

First, online research was done on the available data, then different phone calls and e-mails where conducted with the municipality and the transport companies, asking for the available datasets along the study period (e.g., vehicle registrations, public transport usage). When this data came, more online search was done to make sure that they are representative by knowing how this data was collected.

Later, a filtration and information comparison processes took place. During the filtration process, it was discovered that some of the information is contradicting; thus, the need for interviews and qualitative data was found to be urgent for validation. The final datasets selection came after conducting the interviews and ensuring the collected information through the interview's questions and the literature reviews.

Since the study aims at testing the extent to which the policy influences the usage of transport, inferential techniques (T-test, ANOVA, Correlations) are most suitable. As they focus on explaining the relations between variables and viewing the systematic pattern of change and variation between them and proving their extent of significance (Van Thiel, 2014). Hence for the data processing step, a T-test (to compare before and after the policy), an ANOVA (to see the variation in modes usage) and correlations (to see whether the variation is related or not) applied on the different datasets when needed to answer the research sub-questions.

Semi-structured interviews:

The interview questions were formulated based on the gap in the literature and in the collected statistical data, for the need to confirm its validity. They were also designed to cover the parts of the research, which was not measured statistically in the literature (e.g., perspectives on user awareness, reasons behind different policy measures, contextual arrangements). The interviews were analyzed using professional coding and categorization software (ATLAS.ti 8).

Interviewees were selected based on their expertise in the three research sub-variables (see chapter 4, section 4.5). Three versions of the interviews were made to cover the specialization of all experts (see annex 1). All are covering the main research sub-variables. Prior to conducting the interviews, seven pilot interviews were conducted with researchers from the field of mobility and transportation. However, during the interviews and along with data collection, the questions were subjected to continuous editing and reformulation, to make sure that the used terminologies are correct.

The interviews were conducted and recorded through online applications (Zoom, skype). All the required indicators were covered through the seven interviews. The recordings were transcribed and corrected grammatically through online applications (Otter, Grammarly). Then the transcripts were sent back to the interviewees (member checking) for validation and reassurance of the information. Hence, more points and recommendations were discussed and edited through e-mail-based conversations.

The final step for the interviews was to start coding and categorization. This was done in the same order as the research variables and sub-variables (Figure 3.2.). During this stage, important points appeared to have an impact on the study, which was not in the initial proposal (e.g., political aspects). Hence, the research' conceptual framework was edited.

Name	Grounded
Rotterdam Mobility Approaches	0
SV: ST: AMoT: Active Travel	38
SV: ST: AMoT: Modal Share	68
SV: ST: AMoT: Public Transport	55
SV: TBE: LEZ: Implementation	63
SV: TBE: LEZ: Political aspects	42
SV: TBE: LEZ: Targets	165
SV: TPP: RTP: Infrastructure Connections	60
SV: TPP: RTP: Park & Ride System	31
SV: TPP: RTP: Promotional Campaigns	43
T: Sustainable Transportation	0
T: Transport Based Emissions	0
T: Transport Policy Packages	0
V: ST: Alternative Modes of Transport	0
V: TBE: Low Emission Zones Policy	0
V: TPP: Rotterdam Traffic Plan	0

Figure 3.2.: Data coding and categorization

As mentioned in (Van Thiel, 2014), it is most applicable for this type of research to use thematic and interpretative coding to develop both results on governments motives, and residents' patterns. After this, through axial coding, patterns are detected, matched, and then presented in quotation boxes and through the text.

Therefore, the final data are coded, categorized, and labeled up to the level of sub-variables and then compared. Co-occurrences and frequency of intersection between variables are discussed through presenting the quotations and the repetition of ideas in the text.

Thus, by the end of the results, a solid set of findings, and a framework for policy recommendation was created.

3.4 Operationalization:

3.4.1 Definition of main concepts and variables:

This section identifies the definition of the main concepts and variables that are used in the study. As identified within the scope of the research, this thesis is more linked to concepts of *Low-emission mobility*, *transport policies,* and *sustainable transport*. Where *Low-emission zones policy,* the *Rotterdam traffic plan*, and the *alternative modes of transport* are respectively the derived subjects of these concepts.

Concept: Low-emission mobility

The definition of low-emission mobility varies in the literature. However, it is mostly referred to as mobility that does not contribute to the production of harmful emissions (e.g., active mobility), or that contributes with the least possible effect (e.g., public transport, electric mobility, and shared mobility) (Hulkkonen et al., 2020; Markvica et al., 2017).

i. Variable: Low emission Zones policy:

LEZ is one of the governmental policy approaches to reach the air quality targets for inner cities within the internationally agreed-upon duration. (Ellison et al., 2013). Low emissions zones are areas (mainly between city centers and ring roads) in which the entrance of vehicles that do not apply to a specified emission standard are banned, or highly finned if they enter (Ellison et al., 2013; Fensterer et al., 2014).

Concept: Transport policies

Transport policies are basically described as policies and induced measures that deal with transport problems (Wang, 2010). The success of future cities lies under creating a city where users no longer need to use their cars. Instead, they will have affordability, proximity, health, and open spaces. Hence, transport policies must focus on the social dimension, accessibility, modal shifts, open spaces, and integration of people with traffic (Banister, 2008).

ii. Variable: Rotterdam Traffic Plan:

It is a plan including short- and long-term actions and initiatives that contribute to an overall goal, which is a "Smart accessible, healthy, economically strong, and attractive city". This goal is approached in the document through integrative mobility planning that falls under both, the city 2030 vision, and the mobility agenda (Gemeente Rotterdam, 2017).

<u>Concept: Sustainable transport</u>

Sustainable transport is "transportation services that reflect the full social and environmental costs of their provision; that respect carrying capacity; and balances the needs for mobility and safety with the needs for access, environmental quality, and neighborhood livability" (Jordan and Horan, 1997, Cited in: Jabareen, 2006, p.3). From this, sustainable transport can include electric mobility, public transport, and active traveling.

iii. Variable: Alternative modes of transport:

In most of the literature, this term was mentioned to imply "Sustainable modes of transport" or "Public modes of transport."(Stradling, 2011). Thus, for the purpose of this research, alternatives transport can include electric-mobility, public transport (as it participates in pollution reduction), and active traveling.

3.5 Operationalization of variables

The following table (3.1) explains the operationalization of variables into sub-variables and shows the targeted indicators, based on the literature review and the previously done research on the topic.

Table 3-1 Operationalization of variables and indicators

Concept	Variable	Sub-variable	No.	Indicator	Source	Collection technique
Low-emission mobility	**Low Emission Zone Policy**	**Achieved Targets**	I. 1	The calculated traffic NO_x and EC (Soot) emissions per year.	Municipality + TNO report.	*Real-time passenger data *Secondary data from reports. *Semi-structured interviews
			I. 2	Annual Counted no. of polluting cars entering different city boundaries.		
			I. 3	Number of cars entering the three city boundaries per year.		
		Implementation	I. 4	Information provision strategies and awareness-raising.	Newspaper + interviews	*Secondary data from reports. *Semi-structured interviews
			I. 5	Number of policy violations per year.		
			I. 6	Political arguments and policy changes over the years.		
			I. 7	Scrappage scheme usage.	Municipality	
Transport policies	**Rotterdam Traffic Plan**	**Infrastructure connections**	I. 8	Annually added public electric charging points	RET+ Municipality +Newspapers	*Secondary data from reports. *Semi-structured interviews
			I. 9	Public transport coverage, provision, and pricing		
			I. 10	Public transport quality and annual disruptions.		
		Park & Ride System	I. 11	Number and usage of P+R parking spots per year for a working day.	Municipality + Literature	*Secondary data from reports. *Semi-structured interviews
			I. 12	Annual metro usage in P+R stations.		
		Promotional campaigns	I. 13	Information provision and user inclusion strategies.	Municipality +Newspapers	*Secondary data from reports. *Semi-structured interviews
Sustainable transport	**Alternative modes of Transport**	**Public transport**	I. 14	Public transport annual number of trips per mode	RET	*Real-time passenger data *Secondary data from reports.
			I. 15	Public transport annual Km traveled per mode		
			I. 16	Annual Metro usage per large stations inside and out the LEZ		
		Active travel	I. 17	Cycling trips per working day (visual counts in selected locations)	Municipality	*Real-time passenger data
		E- mobility	I. 18	Annual number of electric passenger cars registered in Rotterdam	Municipality	*Real-time passenger data *Semi-structured interviews
			I. 19	Annual Km traveled by electric cars in Rotterdam		
		Modal share	I. 20	Annual number of trips per mode in a working day.	Municipality + RET	*Real time passenger data *Secondary data from reports.

In conclusion, all three data sources are continuously validating each other. Each information was collected through the three sources. The operationalization on based on the global measurement methods and the three sets of data sources helped in ensuring the reliability of these sources.

Chapter 4: Presentation of data and analysis

4.1. Introduction

The objective of this research is to measure the influence of the "Low-Emission Zone policy" and the measures proposed in the "Rotterdam traffic plan" on the demand for alternative modes of transport. To meet this objective, the chapter includes the results of the data collection that corresponds to the operationalization and respectively answers each sub-research question.

First, the chapter discloses a description of the context of the LEZ and the Rotterdam traffic plan and the timeline of their application. Then the final sampling and interviewee selection are discussed. From here, both the quantitative and qualitative data results, in line with each research sub-question, are viewed. First, the statistical results are viewed, then the interviews, along with the reports and literature review for triangulation, are discussed. Later the statistical SPSS analysis (T-test, ANOVA, Correlation) is viewed and interpreted. The final section includes a conclusion answering each related sub-question.

4.2. Description of the case

4.2.1. Air Quality Agenda 2015-2018

In May 2015, Rotterdam announced its Air Quality Agenda for 2015-2018. The agenda included different measures to be applied to reach a target of 40% reduction of traffic EC emissions, a fast decrease in NO_x concentration, and a 25% cleaner municipal fleet by 2018.

This reduction is expected to occur due to the following (2015; Rotterdam, G., 2015):

- Enlarging the boundaries of the 2007 city center LEZ and extending its scope to include passenger vehicles and vans,
- The continuation of the 2014 incentive program (Scrappage scheme),
- Increasing the local EV charging stations.
- Stimulation of awareness, behavior change and innovation,
- Changing fuels for municipal fleet, buses, and shipping,
- Move towards the "Green Deal 010" for zero-emission city logistics,
- Work on changing the vehicle fleet,
- Align the measures with the Rotterdam Mobility Agenda

4.1.1 LEZ Rotterdam 2016

The overall target of the LEZ was changing the inner-city fleet to be less polluting, and to contribute to a 40% reduction in EC and decrease NO_2 concentration by 2018. Therefore, the new boundaries applied in early 2016, included the northern city area above the river, up till the ring road (figure 4.1.).

Furthermore, the city expanded the restriction to ban more vehicles; including (1) Diesel passenger cars and vans older than 31-12-2000, (2) Benzene passenger cars and vans older than 30-06-1992, (3) Logistics vehicles of euro class III and older (Rotterdam, G., 2015).

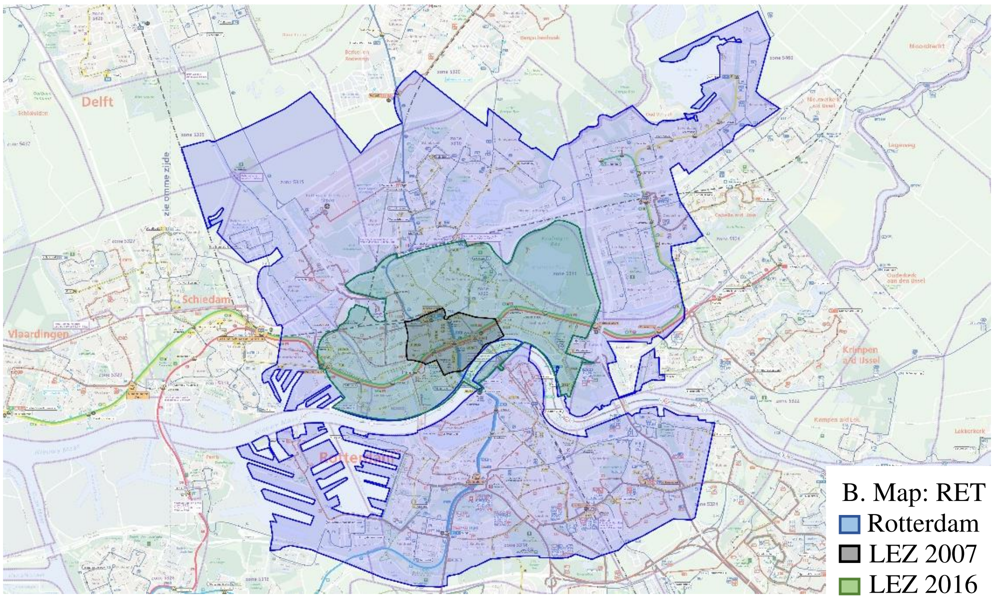


Figure 4.1.: LEZ zoning within Rotterdam; based on (Google, 2020; RET, 2020; Rotterdam, G., 2015)

The policy faced different and multiple objections in the early years, especially from the car owners who did not want to sell their cars, and stated that the amount of polluting cars in the city is very little compared to other emitters. Hence, a court case was filed against the environmental exemption of 2016 (Council, 2018). In 2018 a compromise was made to change the scope of the policy, where the Benzene passenger cars were allowed to enter the zone. At the same time, the rest was kept under the ban until 2020 (Rotterdam, G., 2020).

4.2.2. Rotterdam Mobility Agenda and Traffic Plan

Starting from 2015 and in line with the Air Quality Agenda, the city introduced the Rotterdam Mobility agenda (RMA) 2015-2018, providing more comprehensive policy measures that work on the improvement of public transport, active mobility, and air quality. The Air Quality Agenda was entitled under the new RMA. However, by 2016 an extension of this RMA was required to include more realistic implementation details on the development projects corresponding to each policy measure (Rotterdam, G., 2015; 2017).

Therefore, in 2017 a new long-term traffic plan was introduced with the same overall target; "smart accessibility for a healthy, economically strong and attractive" city. The Rotterdam Traffic plan worked as an umbrella that covers all the actions from 2015 until 2030. It included different measures, initiatives, and projects. In which the municipality focused its attention on stimulating less traffic in the city (within the ring road) and providing sustainable transport (chapter 2, section 2.2.2).

<u>These measures are planned to be achieved through:</u>

- Boosting a cleaner fleet by providing facilities for electric cars.
- Expanding the regional connections and the river crossings, so that both external city visitors and distanced residence can have a fast alternative to the car.
- Offering more internal city connections, so that the short trips (3-5 Km) within the city ring can be entirely replaced by public transport and active mobility
- For the city center, a plan to decrease the Coolsingel's car lanes to create more space to cyclists and pedestrians.
- Improving the P+R facilities and linking it to the LEZ (Rotterdam, G., 2017).

However, since the traffic plan is a long-term plan that includes large projects, this thesis investigates the short-term measures with a specific focus on the LEZ related ones.

- The LEZ and the changes that happened to it, highlighting the reason for that change.
- The change in EV fleet, its infrastructure, and the effect of the other policies on it.
- The scrappage scheme, which was introduced before the LEZ and was extended for the benefit of the LEZ.
- The park and ride system which existed since around 1998, yet it can act now as a solution for polluting cars owners.
- The public transport usage and the change in infrastructure connections and stations.
- The users' awareness and its stimulation through promotional campaigns.

4.2.3. Timeline of intersection

Based on the municipality documents and on the discussion with the experts, it was shown that the city kept changing and adapting different policies, testing their relevance, and increasing the level of details within each phase.

Figure (4.2.) shows the timeline of the selected measures for the scope of this research. The year of the start of each measure, its year of inclusion under the traffic plan, and its relation to the LEZ, it also highlights the major changes that occurred to the LEZ.

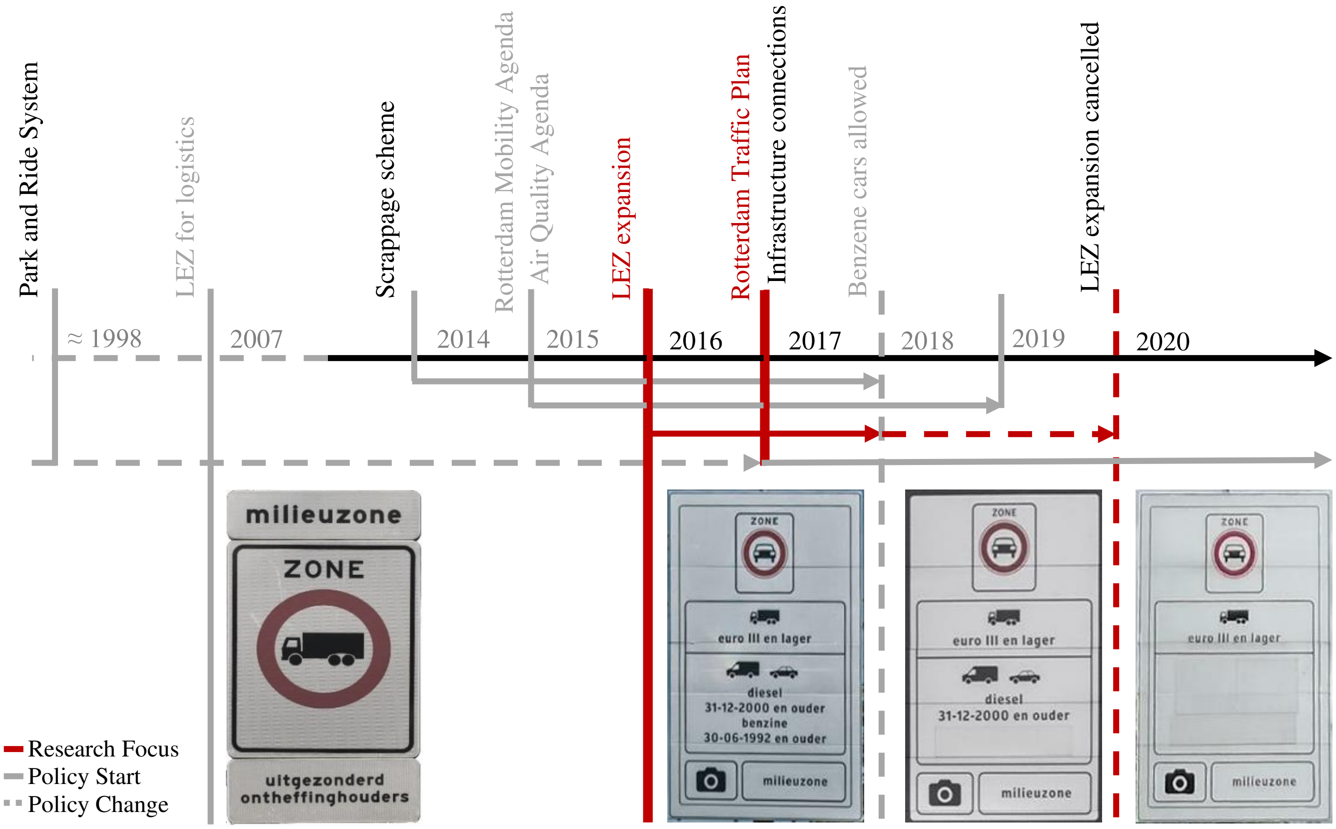


Figure 4.2 : Timeline of policy measures and change in plans (Attia, 2020) ; based on (Rotterdam, 2015; Rotterdam, 2017)

4.3. Description of the sample

4.3.1. Sample for the statistical and monitoring data

The research population is all mobility users, which include not only the inhabitants, but also visitors and passers-by. Therefore most of the analysis is based on the number of trips per mode in the whole city.

<u>The data is collected from different sources, as follows:</u>

- **RET passenger trips and km traveled:** collected through counting the OV-pass check-ins per day, shared privately from the RET, or found in their online reports.
- **Municipality passengers' data:** All the data collected from the municipality are based on visual counts studies that the municipality performs every year with the help of different organizations (e.g., TNO). These studies count vehicle users' with a license checking without counting the same vehicle twice. The same study is repeated annually in the same months for the same camera locations, therefore it has a high level of validity.

- **Infrastructure Data:** The data used for the infrastructure connections (e.g., number of EV charging spots) come from shared data sets from either the municipality or private data collection companies. This data is trusted and assign for real quantities.

These are the main datasets used, the scope is for all city users; therefore, to be consistent, the research excluded any survey-based datasets, especially for statistical analysis. However, the municipality and the CBS surveys results (CBS, 2020; Rotterdam, G., 2020), are used in some of the graphs, as a backup data for the discussion.

4.3.2. Interviewees sampling

For the semi-structured interviews, purposive sampling is applied to select experts who worked with the LEZ (inside and outside of Rotterdam), politicians, and official policymakers from Rotterdam. Experts were selected with different backgrounds and scopes of interests (traffic control, road emission, sustainable mobility, and parking policies) to cover the missing links between the LEZ and the traffic planning in European cities.

Out of 20 approached expert, politician, and policymaker (and through recommendations from them), the final interviewee's sample included the following eight respondents: two key mobility experts who worked with the LEZ in Rotterdam, one key mobility experts who worked with the traffic plan in Rotterdam, one sustainable mobility professor from Rotterdam, and four other experts from different institutions around Europe (Table 4.1).

Table 4-1: Final interviewees sample

	FIELD	TITLE	CONTEXT
Interviewee 1	Senior mobility advisor (Gemeente)	LEZ policy maker	Rotterdam
Interviewee 2	Mobility management and parking policies	LEZ advisor & PhD researcher	Rotterdam
Interviewee 3	Senior mobility advisor (Gemeente)	Traffic Plan maker	Rotterdam
Interviewee 4	Traffic control and intersection	PhD researcher	Delft
Interviewee 5	Sustainable mobility, ports and policies	Professor, expert	Rotterdam
Interviewee 6	Vehicles' emissions expert	PhD engineer/researcher	Brussels
Interviewee 7	LEZ expert and policymaker	LEZ and policies researcher	Paris
Interviewee 8	Urban planning and mobility advisor	Researcher, advisor	Rotterdam

4.4. Presentation and analysis of data of research questions

The analysis is in line with the research sub-questions. Each section starts with the results of the variables, sub-variables, and indicators that answer the corresponding sub-question (Figure 4.3.). Since the secondary data is the main source for this research, each section will start with graphs and/or data from secondary sources, then a summary of the most important interview responses. At the same time, the literature review will be used along with all results to back-up and triangulate (Chapter 3, Figure 3.1.). The final section in each question shows the statistical analysis results.

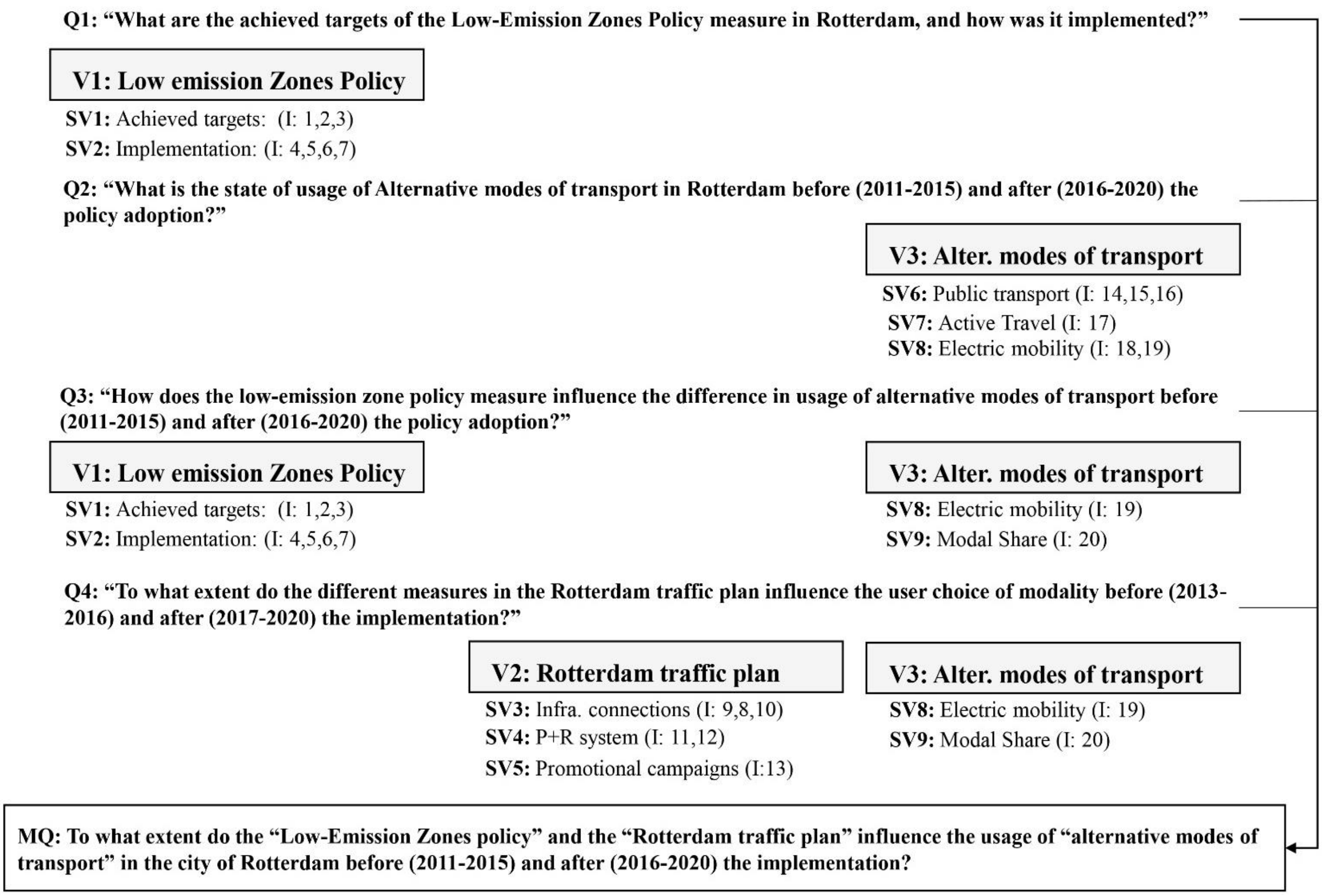


Figure 4.3 : Framework of data analysis and presentation

Figure 4.3. shows the relationship of the variable with each research question. The Figure also shows the sub-variables and indicators that correspond to each of the questions, all leading to answer the main research question. The sequence of this chapter is based on the variables that correspond to each sub-question. Starting with the *Low-emission zones policy* (4.4.1.), followed by the *Alternative modes of transport* (4.4.2.). Then the *Low-emission zones policy influence on the alternative modes of transport* (4.4.3.). Finally, the *Rotterdam traffic plan influence on alternative modes of transport* (4.4.4.).

4.4.1. Low emission zones policy

The first research independent variable is the *Low-emission zones policy*. Alone, it answers the first sub-question sufficiency. This section includes the descriptive statistics, the interviewee quotes, and the literature review results that answer the sub-question: **"What are the achieved targets of the Low-Emission Zones Policy measure in Rotterdam, and how was it implemented?".** The question is answered through the analysis of the two sub-variables "achieved targets" and "implementation," including the seven indicators under these sub-variables.

4.4.1.1. Achieved targets

As mentioned earlier (4.2. Description of the case), the policy had the two main targets. (1) Contribution to the inner-city emission reduction (measured by the indicator "calculated traffic NOx and EC (Elementary Carbon) emissions per year"). (2) Cleaner inner-city fleet (measured through the indicator "Annual counted number of polluting cars entering different city boundaries").

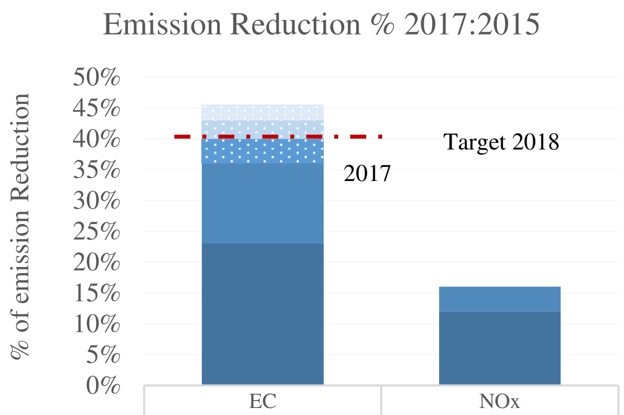
Whereas, to have a comprehensive connection with the vehicle usage, by measuring the effect of the policy on car entry in the city. The following is added under the achieved targets (3) Change in the car traffic distribution within the different city boundaries (measured through the indicator "number of cars entering the three city boundaries per year").

i. The calculated traffic NOx and EC emissions per year

Since the main target for the policy is contributing to the low emission targets of the Air Quality Agenda 2015-2018, in February 2018, the municipality ran an emission evaluation week with the help of the TNO. Road emissions in 6 specific locations (four inside LEZ and two outside) in 2018, were measured and compared with the same location's measurement in 2015 (Stelwagen and Eijk, 2018).

Figure 4.4 shows the results of the TNO study. Compared to 2015, a total decrease of 36% in EC emissions, and a 16% in NO_x emissions occurred in 2017. The study proved that 12% of the NO_x and 23% of the EC decrease occurred due to the measures applied in the Air Quality Agenda (Rotterdam, G., 2018; Stelwagen and Eijk, 2018).

From these results and by calculating the effect of vehicles (per type of engine), the TNO showed that the banning of older diesel passenger cars has a good impact on the reduction of EC only. At the same time, the ban of both diesel and benzene passenger cars have an impact on the NO_x concentration as well (Rotterdam, G., 2018; Stelwagen and Eijk, 2018).



	EC	NOx
Future 2020	2.5%	
Future 2019	3%	
Future 2018	4%	
Natural	13%	4%
AQ agenda	23%	12%

Figure 4.4 : emission reduction in 2017 compared to 2015 + predictions for 2020; based on (Rotterdam, G., 2018; Stelwagen and Eijk, 2018)

Based on the achieved decrease, to reach the main target 40% EC reduction, it was suggested that the LEZ measures should continue till 2020. To keep the measurement low and protect the air quality from degradation. For this suggestion, Figure 4.4 also shows EC predictions (Dotted blue) for the following three years (2018-2020). The expectation promised a 46% decrease in EC if the policy was kept until 2020 (Rotterdam, G., 2018; Stelwagen and Eijk, 2018).

<u>Experts' perspective on the effect of LEZ on the road emission reduction:</u>

It is observed that the eight experts trust the effect of the LEZ on air quality in general. However, in the case of Rotterdam, they agreed on the need for a larger scope of restrictions, for the policy to have an impact. They also suggested that governments must have a prior study that proves the impact of the LEZ on the existing cars. Box 4.1. shows an example of the most important and frequent responses.

> *"it contributed a lot to the improvement of the air quality in Rotterdam. At the same time, you see that the old cars that are banned from the LEZ are rather limited in number. Which it means that there is a huge volume of cars that are still able to come into the city…"* (Interviewee 5)
>
> *"When Rotterdam municipality decided to introduce the LEZ, they commissioned us to do a study and we found out that only 4% of the whole people in Rotterdam were not allowed to enter the area… The point is that when it comes to passenger cars, it pretty much depends on how you enforce it and which kind of criteria you set for entering the zone…"* (Interviewee 2)
>
> *"It depends on the percentage of real polluting vehicles…if you have a lot of old-fashioned polluting diesels then the effect will be large."* (Interviewee 4)

Box 4.1 : Interviewee responses on the effect of LEZ on air quality

ii. Annual counted number of polluting cars entering different city boundaries

One of the expected main effects of the LEZ was to replace the road fleet into a cleaner one (Ellison et al., 2013). Therefore, any LEZ evaluation should focus on the road fleet that enter the city rather than on the overall car registered types of engines. This is the method used by the municipality in the LEZ evaluation report (Rotterdam, G., 2018). For this indicator, data from the TNO fleet scan for six different locations in Rotterdam (two outside the LEZ and four inside LEZ) is used (Stelwagen and Eijk, 2018).

The data represents visual counts for polluting passenger car crossings in these locations for each year. The polluting cars are identified based on their euro class and type of engine (see chapter 2 table 2-1.). Within the dataset, diesel cars E0-E3, and Benzene cars of E0 is counted.

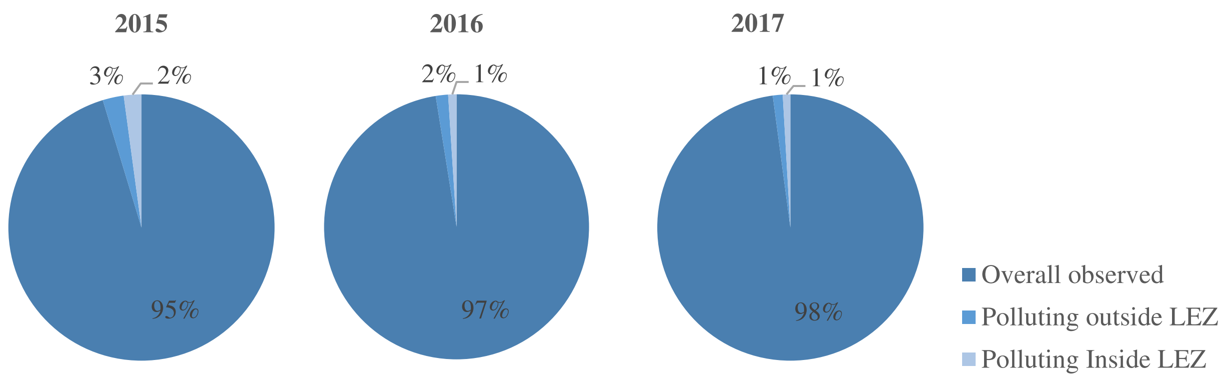
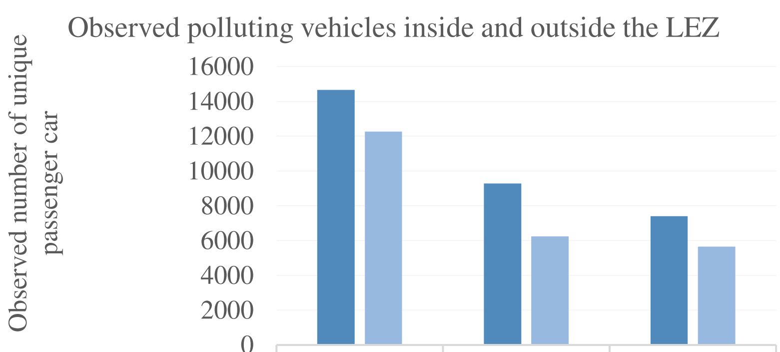


Figure 4.5 : Annual percentage of polluting cars entering the city compared to overall car crossings.

Figure 4.5 shows the percentage of polluting cars compared to the overall observations at the 6 locations in the three years of measurement. Polluting cars accounted only for 5% of the overall cars in the city before the LEZ. However, it went down to 2% in 2017. The following graph gives more insights into the polluting cars division.



	2015	2016	2017
Polluting outside LEZ	14653	9281	7393
Polluting Inside LEZ	12263	6247	5656

Figure 4.6 : Annual percentage of polluting cars entering the city compared to overall car crossings.

Figure 4.6. shows that the number of polluting cars entering the LEZ decreased to around 50% compared to 2015. The same rate of decrease also applies to outside of the LEZ. Nonetheless, the number of polluting cars outside of the LEZ is always higher than inside.

Experts' opinion on the LEZ effect on fleet composition in Rotterdam:

Out of the 5 Rotterdam's experts, 3 doubted the effect of the Rotterdam LEZ on the change in the overall car fleet. They believe that the effect is very small compared to the overall car fleet. And that the policy shall either be replaced by measures to support less traffic, or have more strict measures and a larger scope. While at the same time, the policy package shall work on solving the social and political issues that will arise from the large scope of restrictions.

Their argument was supported by the three external experts. From their experience with LEZ outside of Rotterdam, they also support the idea of more strict regulations. However, they suggest that the government must spend more time in providing alternatives and solving the political issues before they start the policy.

While the other 2 Rotterdam experts were more thinking of the policy as a part of an overall Air Quality package that must be applied together to lessen the social and political objections. Their argument is supported by the TNO study, which considered the decrease in polluting cars is partially due to the LEZ policy (Stelwagen and Eijk, 2018). Even though the number of polluting cars is too little (5%), the city so far succeeded in meeting its identified target (chapter 4, 4.4.1.1.), and the policy has a significant share in that. Box 4.1. illustrates the most significant quotes with respect to the change in the Rotterdam fleet.

"The VVD political party was against the LEZ they thought that too little cars was affected, specially the old petrol cars, they said the measure of LEZ is too big for such a small portion of passenger cars… (Interviewee 1).

"If you want to be successful, a lot of people should not be able to enter the area. But the more people cannot enter the area, the more people will complain...So, it's a political problem" (Interviewee 2)

"…the main thing is to know how to support people, either to replace their vehicles or replace their way of transportation. It is important that people know what to do and how to do it." (Interviewee 7).

Box 4.2 : Interviewee responses on the effect of LEZ on the change in the road fleet.

Furthermore, through the CBS calculation for the car registry in Rotterdam 2017, it was proved that the LEZ, was part of the reason for the decrease in the registered old light diesel vehicles (Geerlings et al., 2020). Where, "the number of vehicles has almost halved to 2 200 units” in 2017 compared to 2016 (CBS, 2017, p.1). However, this data account for only one year, it is not very representative, and the reasons can be different (e.g., scrappage scheme).

iii. Number of cars entering the three city boundaries per year

Since both Rotterdammers and visitors with polluting vehicles are supposed to not enter the zone, there must be an impact on the amount of car trips within the zone. To measure the car entry in the LEZ and outside of it, and compare it with the timeline before and after 2016, there is no annual comprehensive data collected on that regard (The TNO data is not representative for that purpose and does not cover the whole period). To solve this and to give an impression on the policy achievements, data from city cordon entering cameras for around 200 locations will be used (Rotterdam, G., 2019).

Figure 4.7 shows the three city cordons, as divided by the municipality (Rotterdam, G., 2019). Based on the provided map and on the fact that “The concentration of traffic-based air pollution is the largest North of the River” (Rotterdam, G., 2015, p.9), the ring road cordon will be used to give an impression on the LEZ entry before and after the policy application. Hence the map shows the intersection between the LEZ and the ring road cordon.

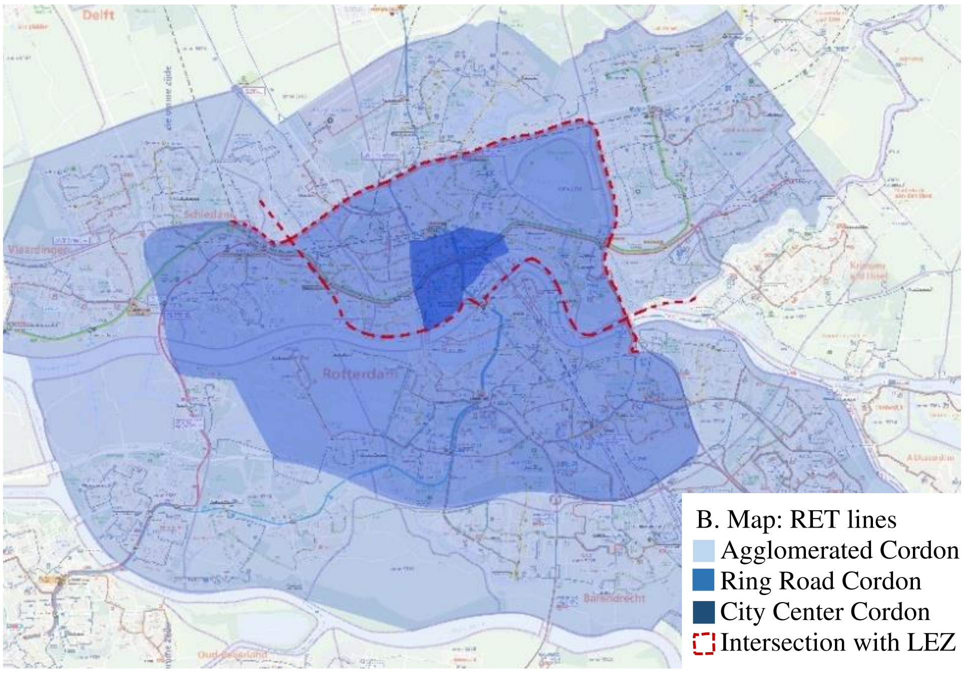
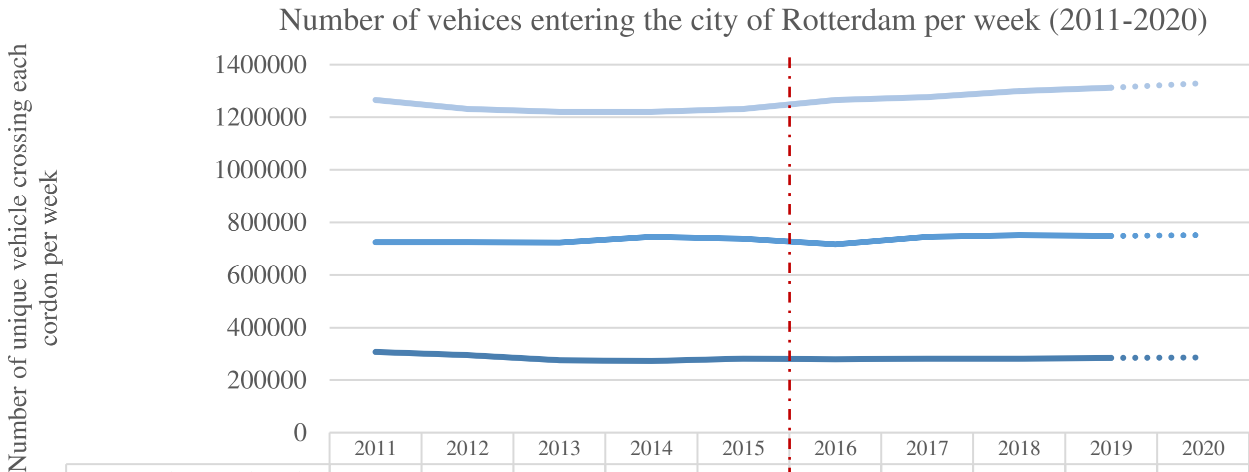


Figure 4.7 : Rotterdam city cordons and LEZ; based on (RET, 2020; Rotterdam, G., 2015; Rotterdam, G., 2019)

The following Figure 4.8 shows the entry counts per week for each city cordon for the period from 2011 till 2020 (Rotterdam, G., 2019). The final year (dotted blue bar) is estimated for the comparison to include five years before and after 2016 (the index year, dash-dotted red).

The graph (figure 4.8) shows that before 2016 there was a slight decrease in the agglomerated cordon compared to 2011. However, after 2016 an accelerated increase occurred for car passages in that cordon.

As for the Ring road cordon, the number of car passages kept slightly increasing over the years since 2011, with a small drop-down in 2016, which then went back up until 2019 with another very slight drop. As for the city center cordon, the numbers were decreasing all the way until 2015, and then it kept an average of 280000 cars per year after that and until 2019.



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Agglomerated Cordon	1265697	1231795	1220493	1220493	1231794	1265697	1276998	1299600	1312408	1329521
Ringroad Cordon	723667	723667	723406	744476	737453	716383	744476	751500	748222	751634
City Center Cordon	306848	294324	275537	272406	281800	278668	281800	281800	284305	285915

Figure 4.8 : Visual counts for overall car entry in different city cordons based on (Rotterdam, G., 2019)

This difference in variation can mean that starting from 2016, a percentage of the city visitors, who were captured at the agglomerated cordon stop before entering the ring road, they either park outside or are no longer using the inner-city streets. The same happens to a percentage of the ring road users. To measure the influence of the LEZ on this difference in variation, further statistical analysis is required (See chapter 4, 4.4.4.4.).

<u>Experts' opinion on the reduction of car usage in different city cordons:</u>

The 5 Rotterdam experts agreed that the policy was not intended to reduce the number of car entries. Three of the experts mentioned that Rotterdam is originally a car-oriented city. Especially since after it was bombed. The city was redesigned with large streets and car supportive infrastructure. Hence, it is difficult to approach the decrease in traffic through the LEZ measure without support for alternatives (Rotterdam: the City Rebuilt for Cars, 2020; Runyon, 1969). Box 4.3. shows an example of their responses.

"*This was not a problem. So, it had nothing to do with the number of cars. It had more to do with the age of the cars and the quality of the emissions*." (Interviewee 5)

"Rotterdam is a city made for cars, it was always advertised for as a car city, you cannot change that in one day" (Interviewee 8)

Box 4.4 : policy targets

While, when asked about the practical application of the LEZ, all experts encouraged the coupling of the policy with different other measures to attract the people to stop using their car inside the city. These measures shall be included in a large long-term vision that is ready to face the social and political problems (Box 4.4.).

"I would say because that is the big problem in Rotterdam. Start with is a vision and then be consequent in your policymaking" (Interviewee 5)

Box 4.3 : LEZ policymaking

From these measures, the provision of alternatives and decreasing the inner-city parking was discussed in all interviews. While making the city centers more attractive for active mobility was discussed in four interviews, especially from the side of traffic experts. Box 4.5. illustrates the most significant quotes with respect to the decrease in the Rotterdam fleet.

"*Make the city centre attractive to go by bicycle, by foot so make it wider for cyclists indeed and more cycle path, and less car or provide shared cars…"* (Interviewee 4)

"…the main thing is working on the carparks. So, if you reduce the car parks, then cars cannot come anymore." (Interviewee 7)

Box 4.5 : LEZ policy package.

To conclude, based on these discussions, it is clear why the ring road cordon was almost not affected in the graph before and after 2016. The reduction of car entry inside the city was not the target, to begin with. The results for the interviews highlighted the importance of studying the status of alternatives and the different policies that were applied in line with the LEZ.

4.4.1.2. Implementation

The second sub-variable for this sub-question is the "Implementation" of the LEZ policy. The policy faced different challenges and struggles during implementation (Chapter 4, 4.2.2.). These challenges are measured through the two qualitative indicators "information provision strategies and awareness-raising" and "political arguments and policy changes over the years" from the interviews, online articles, and reports. And the two quantitative indicators, "the number of policy violations per year" and "scrappage scheme usage," which are based on the quantitative data collection done by the municipality. This section will discuss these four indicators in detail.

i. Information provision and awareness-raising

Provision of information and awareness-raising are amongst the most critical and important steps in the implementation of the LEZ policy. In Rotterdam, the municipality took a step by step approach to inform the citizens. LEZ was first advertised for, in mid-2015 within the Air Quality Agenda Release (Rotterdam, G., 2015). The agenda included the age of restricted vehicles, the air quality target, and a description of the reasons for the ban. The LEZ was introduced as a temporary measure to be withdrawn whenever the emission target is achieved.

Based on the interviews with the policymakers in Rotterdam, it is clear how important it was to advertise for the policy clearly, stating the reasons, before its application. Hence, the LEZ was advertised to, from the perspective of air quality and pollution reduction, as these aspects are guaranteed to have a certain degree of understanding within the users. As an attachment and a complementary promoting strategy, the scrappage scheme can always be advertised within the LEZ information (Mingardo, 2008). Box 4.6. shows the responses related to the LEZ advertisement.

> *"...To promote something, you must invest in communication quite a lot. So, you have to tell very clearly why you do it."* (Interviewee 2)
>
> *"Air quality is very important to most of the people...when we introduced the LEZ in 2015-16, there were a lot of communication actions, we informed the people that there were big debates about Rotterdam clean air through all kinds of alongside roads signage."* (Interviewee 1)
>
> *"Incentives were very helpful and were combined with awareness- campaigns. For people to have the feeling that they can do something by themselves."* (Interviewee 1)

Box 4.6 : LEZ communication strategies

Aside from the formal documents and offers, the policy was also advertised with road signage (Figure 4.9), newspaper, and online media, where they announced the coupling of the scrappage scheme with it (Box 4.7).

Figure 4.9 : Road and floor signage from Rotterdam. Image creadit to: (Harry, 2016; News, 2018)

> *"...residents who are no longer allowed to enter the environmental zone with old and polluting cars are supported by the municipality with an existing but adapted scrapping scheme*" (Autonieuws, 2015, p.1).

Box 4.7 : Example of a newspaper advertisement

Furthermore, during the policy application for drivers to know whether their car can enter the city or not, the municipality applied two information sources. First, there is an open-access license plate checker online on the website of the municipality (Rotterdam, G., 2020), where if they enter the license numbers of a car they can know everything about its emission class and year of admission as well as the possibility of entering the city (Figure 4.10). This is applicable to everyone and connects with all European car databases.

The second way of reaching to the polluting car owners was a street license checker signage on the main LEZ entrances (Figure 4.10). These street signages were inserted in 2016 as instant information for new LEZ users. Even though the policy was set to start from 1 January 2016, the municipality did not apply any fines to the violating cars during the first four months as a strategy for raising awareness before the strict application of the policy (Box 4.8.).

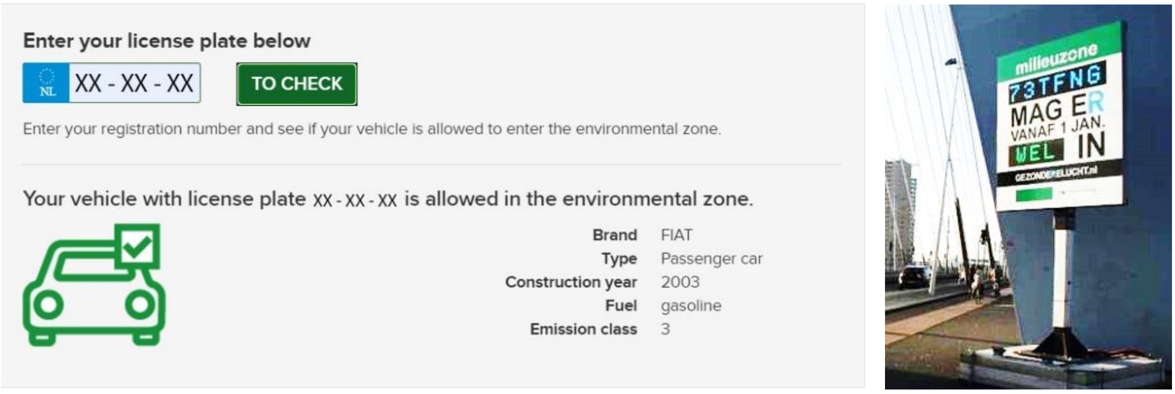


Figure 4.10 : Online (Rotterdam, G., 2020) and street license checkers. Image credits (Interviewee 1).

> *"...the first four months in 2016 and we didn't send fines. But we had very big displays along the road and when the car enters right into the LEZ, we check the number plate with the database in our system. If the car is allowed, then what appears on the big display is 'Okay, you are allowed' and if the car wasn't allowed on the displayed there is 'this number plate isn't allowed'"* (Interviewee 1).

Box 4.8 : Policy application strategy and information provision

From these, we see how the involvement of people and the awareness rising were taken care of, in the case of Rotterdam. However, even with that, there were a few policy violations along the years of application (Priest, 2019), as well as multiple political and social objections.

ii. Political arguments and policy changes over the years

In the initial proposal of this research, the political aspect was not taken into consideration. However, based on the analysis of the result for the LEZ variables, the literature review and the interviews, political struggles seemed to intersect with most of the indicators. It also acted on shaping the timeline and changes of the policy (see the timeline: Figure 4.2.). Hence, it had a repetitive effect on the LEZ implementation in Rotterdam.

<u>Experts' and newspaper discussion on the timeline of the LEZ political struggle:</u>

From the early announcement of the LEZ, there were people protesting and filing complaints about the unfairness of the policy. Where *"One group of opponents went to court, claiming the municipality took insufficient account of their interest and that the measure to ban old petrol cars within the LEZ was disproportionate. Studies showed these cars make up only 0.14% of the traffic in the area"* (Modijefsky; Pieters, 2018). This split the city it halves.

On the one hand, the Groen Links party (Green political party) supported the policy continuation. They were more committed to the air quality targets and believed that LEZ would have a major influence on that (this same idea was enforced by interviewee 1). *"Old Benzene cars are very polluting. They also contribute more than 20% of the reduction of NOx emissions. Keeping this group out is very important for Rotterdam's healthy air. Says: Member of the city council"*(Van Putten, 2017).

On the other hand, the protestors were supported by the VVD party (People's Party for Freedom and Democracy) and together they wanted to stop the policy application specifically for the benzene cars, they backed-up their argument by saying that the number of banned cars are too little to have an impact on air quality (Which is the idea supported by interviewee 2, 3 and 5). Thus, the VVD announced that they are *"…strongly against including petrol cars in a national environmental zone system. Says: VVD Member of Parliament"*(Bakker, 2018, Figure 4.11).


Milieuzone kan alle auto's raken

Kabinet kijkt naar Rotterdam * Uitspraak Raad van State over oude benzineauto's * CDA: hobbyrijders ontzien

Alexander Bakker

Den Haag * Bezitters van oude benzineauto's moeten alsnog vrezen een landelijk systeem voor milieuzones. Staatssecretaris Van Veldhoven (Infrastructuur) was bezig enkel diesels mee te nemen in haar plannen, maar de situatie in Rotterdam dreigt nu roet in het eten te gooien.
Aanleiding is een uitspraak van de Raad van State. De hoogste bestuursrechter oordeelt dat Rotterdam benzineauto's van vóór 1 juli 1992 mag weren uit het centrum. Eerder oordeelde de rechtbank in Rotterdam dat dit verbod niet voor deze categorie mocht gelden.
Aan de onderhandelingstafel voor een nieuw stadsbestuur van Rotterdam moet nu besloten worden of de omstreden milieuzone voor benzineauto's weer terugkomt. Kiest het nieuwe stadsbestuur daarvoor dan wil staatssecretaris Van Veldhoven de oude benzineauto meenemen in haar plannen om 'milieuzones te harmoniseren'. „Het is aan Rotterdam de milieuzone te herstellen", zegt haar woordvoerder. „Doen ze dat niet, dan doen wij er niets mee."
Regeringspartij VVD is fel tegen het opnemen van benzineauto's in een landelijk milieuzonesysteem. „Die komt er niet in", zegt VVD-Kamerlid Remco Dijkstra. „Een milieuzone moet wel proportioneel zijn. Dat is het weren van benzineauto's niet, die zijn zo schoon."

Lappendeken

CDA-Kamerlid Maurits von Martels is niet voor een verbod voor benzineauto's, maar mocht dat er toch komen dan wil hij wel een uitzonderingsregeling voor hobbyrijders met echte oldtimers. Staatssecretaris Van Veldhoven presenteert naar verwachting eind deze maand haar plannen voor milieuzones in Nederland. Ze wil vooral af van de lappendeken van verschillende maatregelen tegen vervuilende auto's.

Figure 4.11 : The LEZ argument (Bakker, 2018)

Hence, from 2016 till July 2018, court cases were opened against and pro the policy (Council, 2018). Where, finally, the judge rules in favor of the opposing group, then the municipality appealed against the ruling, so it receives a pro decision for the policy to continue (Modijefsky, 2018). However, the VVD was still against that final decision. After that, there was an upcoming election, which made the two parties sit together and settle on a final decision, which was the withdrawal of the policy (Box 4.9.).

"Later because of the elections in 2018 there was a new government in the city. The two political parties had to speak together to make a program for the city. The only solution for them where to make a compromise. And then was decided to skip the LEZ for passenger cars and vans, petrol, and diesel, and instead to reduce the total amount of traffic in the city and to provide sustainable alternatives" (Interviewee 1)

Box 4.9 : Policy withdrawal decision

During the elections settlements, they decided to start phasing out the policy step by step by allowing Benzene cars from July 2018 (figure 4.12), then allowing the rest of the Diesel cars and vans starting from January 2020, along with working on the provision of sustainable alternatives and providing a rigid traffic plan (Interviewee 1).

This decision was supported by all parts, especially since the 2017's TNO evaluation, which showed that the air quality levels in Rotterdam is already being improved. Thus, phasing out the policy is not harmful to any of the parties. *"…The ANWB says it is a smart choice to end the environmental zone in Rotterdam. The city found other ways to improve air quality without the need for a fuel car ban. For example, they will use shared electric cars, for which 100 EVs will be made available. They are also setting up a system for shared bicycles."* (BBC, 2019).

Figure 4.12 : Oldtimers celebrating the return to the zone, July 2018. Image credits: Frank de Roo (van Vliet, 2017)

Hence, 3 of Rotterdam interviewees stressed the importance of the social inclusion of the users before any policy application. The larger the scope of restrictions, the more social unease it will get. Where (as suggested by five of the eight interviewees) in the case of traffic policies these struggles, can be solved through providing a strong package of alternatives (Box 4.10.).

"*The social aspect is absolutely fundamental…Yet the more potentially effective is the policy, the more political fights you will get"* (Interviewee 2)

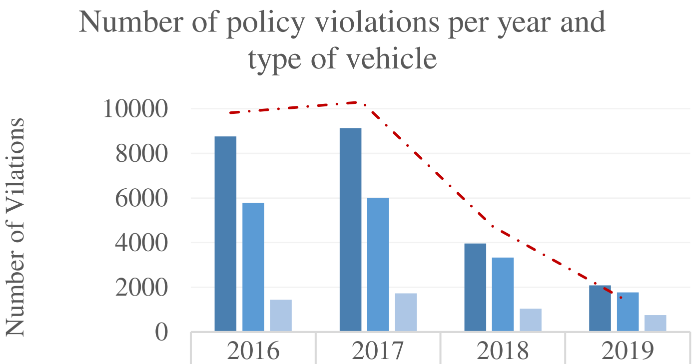
"Every city has its own specific barriers to overcome. Unfortunately, it is not one approach that you can apply. Each city is different, therefore come up as a package and be consequent, have courage to do so." (Interviewee 5)

Box 4.10 Policy withdrawal decision

In conclusion and based on this data, it is shown how important it is to include the people and increase their awareness during the policy decision making as well as to make sure that the number of restricted vehicles is significant to apply the policy. While at the same time, introduce different alternatives to the users in order to have a comprehensive strong and effective policy from the beginning (Tobollik et al., 2016).

iii. Number of policy violations per year

Along the four years of policy application, several violations occurred, which shall be investigated while studying the policy implementation. *"According to De Telegraaf, the municipality of Rotterdam has cashed heavily since its introduction in 2016. With around 47,000 fines…"*(Priest, 2019, p.1).



	2016	2017	2018	2019
Passenger car	8760	9128	3969	2085
Van	5778	6012	3332	1769
Truck	1439	1736	1046	752

Figure 4.13 : LEZ policy violations (Raw data acquired from the municipality)

Figure 4.13 illustrates the number of policy violations along the four years, per type of vehicle. The graph shows how the numbers decrease each year. However, there is a slight increase in 2017 compared to 2016, which can be because the municipality started filing the fines after April 2016, thus 2016 is accounting for only nine months. Whereas in 2018, there is a drop to less than half of the violation compared to 2017. This drop might be a reason for the withdrawal of the benzene cars ban in 2017, where the previous years had more benzene violations (see Box 4.11). It can also be a reason for the increased awareness of the strictness of the policy.

Compared to truck passenger cars and vans have the largest share of violations, this can be because the trucks banning started in 2007, it because of the control of the private sector over the trucks, where there are more strict regulations applied to companies (Interviewee 2 and 5).

<u>Experts' opinion on the reasons behind the policy violations and how to solve it:</u>

Four out of the eight experts explained that policy violation could be a cause of the absence of environmental and policy awareness as well as difficulty in finding a replacement. They suggested to increase the promotional campaigns, direct the awareness towards protecting the environment, and provide more adequate alternatives, as well as infrastructure connections.

While another interesting opinion was that these people might be the group of Oldtimers (Figure 4.14) that do not really care about paying the fine since they are in a good economic term, and they are against the policy from the start. This opinion can explain the drop in the violations between 2017 and 2018 (Figure 4.13), where cars of this category (Figure 4.14) were allowed to enter the zone. Box 4.11. shows the most significant opinions in that matter.

> *"Explain to the people more about the reason why you are doing it. People think it is only one car and they do not realize that many people think "it's only one car""* (Interviewee 4)
>
> *"... in the beginning there was a lot of information but then they stopped with the information so there might be some people that maybe don't go to Rotterdam very often, simply they don't know that there is a LEZ...then the question is Do they know at all, that there is a LEZ? is the problem that they don't know that their car was not fit? Or they did not remember? Second, do they know that there is a P+R?"* (Interviewee 2)
>
> *"Maybe they are the Oldtimers, who protested a lot. They own the cars as a hobby and only use it once a month. In the wintertime if they do not go outside it is not good for the car."* (Interviewee 5).

Box 4.11 : Reasons behind the policy violations

Figure 4.14 : 1965, 1971, 1978's Benzene cars (E0) inside LEZ, Rotterdam Jun-August 2020 (Attia, 2020).

Furthermore, it is critical in this stage to study the usage of the scrappage scheme, to have a better understanding of the fleet composition in Rotterdam and the effect of the LEZ and its coupled measures on the that.

iv. Scrappage scheme usage

The scrappage scheme was intended to support the citizens to replace their old cars. The allocated budget was part of the support for the LEZ policy (CBS, 2017; Rotterdam, G., 2015: Interviewee 1). The subsidy amount depends on the year of construction and the type of car and is between € 1000 and € 2500 (Boer and Erdem, 2017)

Over the years, the program was subjected to many extensions (see the timeline figure 4.2.). In 2017 the program usage frequency was around six applicants per month; by this, it had reached 5100 applicants since March 2014 (Boer and Erdem, 2017). Therefore, for the final year 2018, the municipality assigned a budget of 160000 euros (Scheme extension request: See Annex 3). The overall program usage in December 2018 reached 5300 applicants (Hope, 2019).

Figure 4.15. gives a viewpoint on the choices of the program users for their car replacement based on a survey done by the municipality at the beginning of 2017 (Boer and Erdem, 2017). Out of 4970 program users, the municipality approached 4771 respondents, where 1952 completed the survey. This makes the sample representative since almost 40% of the 2014-2017 users responded (Boer and Erdem, 2017). To construct this figure, the survey results (in percentage) were multiplied by the final overall program usage from 2014 until 2018.

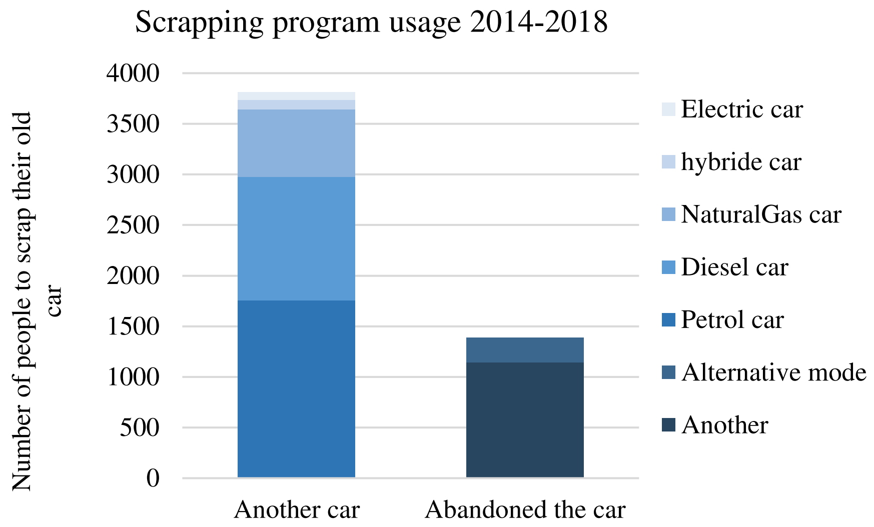


Figure 4.15 : Scrappage scheme usage per type of vehicle. Adapted from (Boer and Erdem, 2017; Hope, 2019).

Figure (4.15.) shows that almost 28% of the scrappage program users tend to not buy a new car with the subsidy money. Out of those 5% (of the total users) switch to an alternative transport mode. While the rest 72% buy a less polluting vehicle. The division of engine type goes in favor of both benzene and diesel cars (together 56%), with a slight increase in the purchasing of benzene than the diesel. On the other hand, a very small number of users turned to electric or hybrid vehicles (together 3%).

The scrappage scheme was successfully used by many users in Rotterdam (Hope, 2019). Old cars are being phased out for the current policy target (20% less emission by 2018). However, even though less polluting cars are being purchased, the environmental awareness for the shift towards a local zero-emission mobility (included under the city 2030 agenda), is doubted, since Diesel and Benzene cars of Euro class 5 and 6 are still allowed (Interviewee 5).

Experts' discussion on the usefulness of the scrappage scheme:

The eight experts agreed that the scrappage scheme is a successful measure, which shall be coupled with the LEZ to guide the transition and decrease the opposition (Box 4.12.). The program has proved its successful application in different European cities (Geerlings et al., 2020).

"It was one of best applied ways for promoting for the LEZ among citizens, I recommend cities to not only ban but also apply incentives like a scrapping program" (Interviewee 1)

"*So, incentive program is first a way of raising awareness among citizens, because otherwise we cannot depend on the individual action.*" (Interviewee 7)

Box 4.12 : Scrappage scheme success

Furthermore, within the context of a sustainable mobility, four out of the eight experts viewed the scheme as a measure that only helps in the reduction of the negative social effects. Hence, it is not helping in the transition towards sustainable mobility, since there is no control over the type or size of means of transport the subsidy user will replace their old car with. One of the experts suggested that the government shall put some regulation to stop the scheme users

"…it helps to reduce the possible social negative effects of transformation, but it's not really meant to reduce pollution or to do other things… They might help a few people to switch from an old car to a less old car or a new car, but it's always a car." (Interviewee 2).

"...the policy must consider, what do you really want in your inner city? Because if you still say, _well! you can swap your car for an electric car, and you can come to the city centre, then the city centre will still be full of cars." (Interviewee 4).

"*Government should focus on public transport and not on helping people buy new cars… And if they focus on incentives, they should focus on people buying small cars, instead of the large, big luxury ones*" (Interviewee 6).

Box 4.13 Scrappage scheme usage

from buying large cars, in order to control the future traffic problems (Box 4.13.).

Hence it can be concluded that experts supported the idea of the scheme to be within the LEZ package if it helps in the main target of the city. However, if the overall target is to reduce the inner-city traffic or to reach a zero-emission fleet in the future, as mentioned in the traffic plan of Rotterdam (Rotterdam, G., 2017), then the program is not helpful for that. Since it does not have an effect on the traffic reduction, and it does not have control over the new purchases.

4.4.1.3. Conclusion

In conclusion, and to answer the first sub-question. The LEZ has proved its early success in achieving its initial targets. This target was the contribution to 40% EC emission reduction, and to the overall reduction of the inner-city NO_x. This success was supported by the packaging of the policy with the scrappage scheme and the promotion for electric transport (Boer and Erdem, 2017; Geerlings et al., 2020; Hope, 2019).

However, during its implementation period, due to the inconsistency of the policy targets and the failure to receive the required social support, the policy passed through several objections until it was put down. Hence, it is greatly advised for a strong policy like the LEZ that it should be previously and transparently advertised for and supported by a strong package of alternatives (Geerlings et al., 2020; Tobollik et al., 2016).

4.4.2. Alternative modes of transport

As the only dependent variable for this research, *Alternative modes of transport* alone answer the second sub-question. This section includes the descriptive analysis, the interviewee quotes, and the secondary data results that answer the research sub-question: **"What is the state of usage of Alternative modes of transport in Rotterdam before (2011-2015) and after (2016-2020) the policy adoption?".** The question is answered through the analysis of the 3 sub-variables: "Public transport," "Active travel," "E-mobility," including 6 of their indicators.

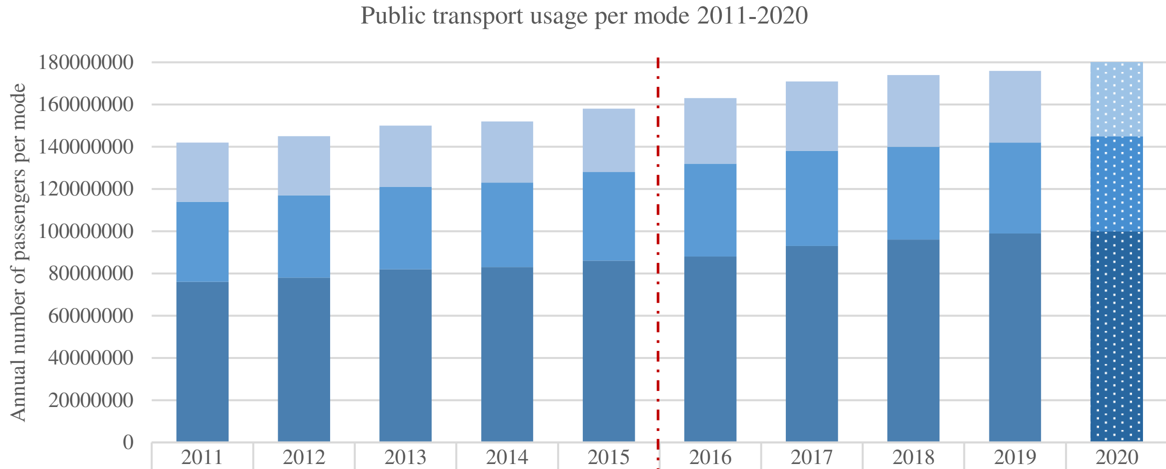
4.4.2.1. Public transport

Rotterdam is characterized by having a very strong public transport network. It covers most of the city with the variation of buses, trams, and metro lines (Rotterdam, G., 2020). The usage of the three modes of public transport in Rotterdam is measured through the two indicators "Public transport annual number of trips per mode" and "Public transport annual km traveled per mode." For this research, a third indicator: "annual metro usage per large stations inside and outside of the LEZ" is brought to strengthen the policy influence in different locations over the period of the past ten years and to be able to compare the usage inside and outside the LEZ.

The data in this sub-variable is measured by the RET through annual unique passenger usage per mode (RET, 2020). The year 2020 (dotted bar) is estimated based on the natural increase to have a comprehensive comparison (5 years to 5 years).

i. Public transport annual number of trips per mode

Figure 4.16 shows that the overall public transport usage keeps increasing through the years. The Figure illustrates the dominance of the metro line usage in Rotterdam, where it is almost used as much as both buses and trams together. Nonetheless, in the period after the LEZ application (Dashed red line), the overall increase is slightly accelerated. This could be due to the LEZ application, the traffic plan infrastructure connections, users' environmental awareness or can be natural due to the increase in overall activity. Therefore, this implies further statistical analysis in comparison to other modes (Chapter 4, 4.4.2.4.).



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Bus	28000000	28000000	29000000	29000000	30000000	31000000	33000000	34000000	34000000	35000000
Tram	38000000	39000000	39000000	40000000	42000000	44000000	45000000	44000000	43000000	45000000
Metro	76000000	78000000	82000000	83000000	86000000	88000000	93000000	96000000	99000000	100000000

Figure 4.16 Annual number of passenger trips per mode. Data aquired from (RET, 2020)

ii. Public transport annual Km traveled per mode

To give an overall indication of the actual usage of public transport, the following figure (4.17) shows the annual km traveled by public transport per mode in Rotterdam.

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Bus	88,000,00	94,000,00	107,000,0	109,000,0	114,000,0	118,000,0	139,000,0	146,000,0	143,000,0	154,714,2
Tram	109,000,0	112,000,0	114,000,0	117,000,0	124,000,0	130,000,0	133,000,0	131,000,0	129,000,0	137,142,8
Metro	460,000,0	472,000,0	509,000,0	531,000,0	556,000,0	559,000,0	599,000,0	618,000,0	649,000,0	665,428,5

Figure 4.17 Annual km travelled by public transport per mode. Data acquired from (RET, 2020)

Figure 4.17 proves the dominance of the metro line usage, where when measured in km, the metro is used 5.5 times more than each of the busses and the trams. This can be due to the larger metro coverage and the speed that it provides (RET, 2020). Furthermore, the graph highlights the acceleration of the increase in the usage of transport. A noticeable increase happened in 2017 (dashed grey line), which is the year of the traffic plan 2017-2030+ activation. This also implies the need for further statistical analysis (Chapter 4, 4.4.2.4.).

iii. Annual metro usage per large stations inside and outside of the LEZ

After identifying the accelerated increase in transport usage before and after 2016, it is important to know whether this increase is inside or outside the zone (to answer the main research question). The map in Figure 4.18 shows 28 selected stations inside and outside the LEZ. There is no data available currently on the trams and buses (RET expert, through e-mails). Therefore, these 28 stations are selected because they have an intersection of transportation (tram, bus, Metro). Nonetheless, the stations outside the LEZ are characterized by having P+R spots. The data is collected per working day, twice a year (March and November mostly), and the studied results are average for each year.

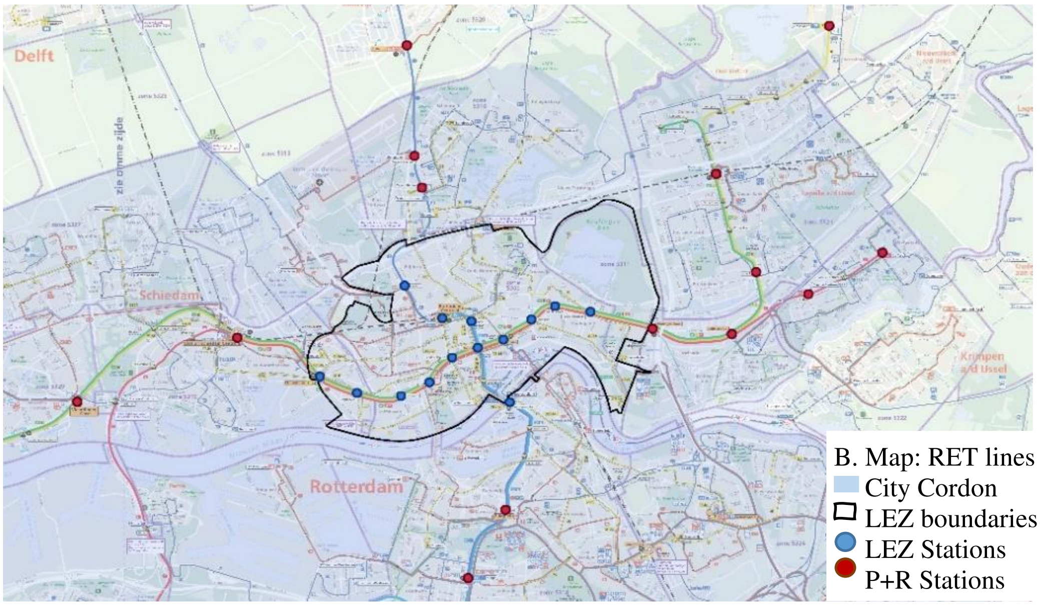


Figure 4.18 : Selected stations for the study and their relationship with the LEZ. Based on (RET, 2020; Rotterdam, 2015)

Figure 4.19 shows a significant variation between the Metro usage inside and outside of the LEZ. Even though the 28 stations are all relatively large ones, the stations inside the LEZ have almost double the usage of outside. However, this large difference is similar since 2011.

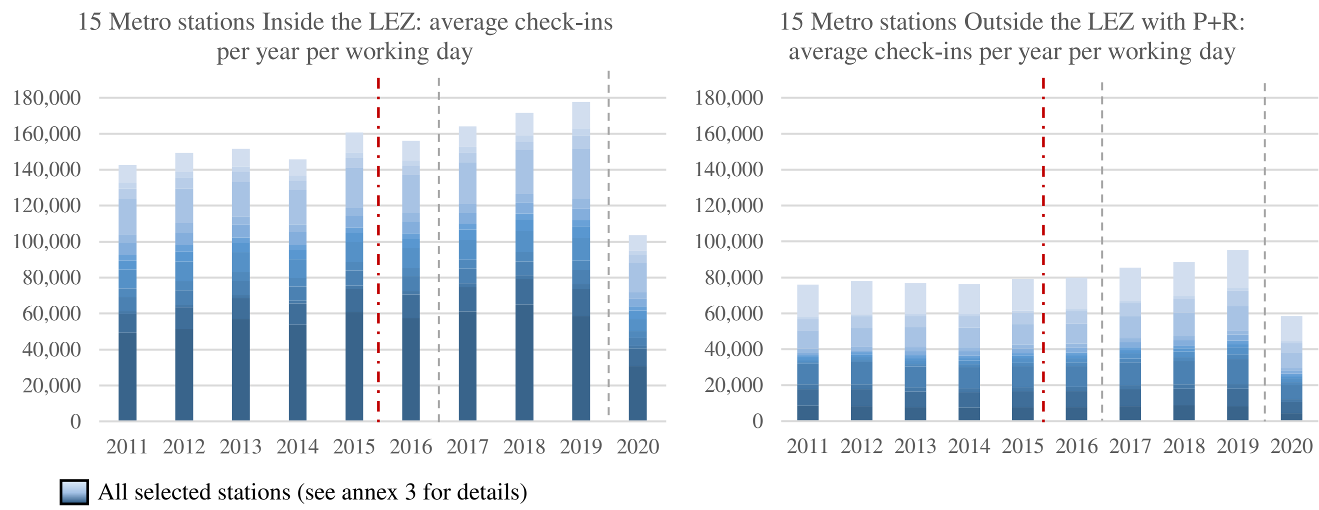


Figure 4.19 : Metro usage in 28 main stations inside and outside the LEZ. Data aquired from (RET, 2020)

According to (Kinigadner et al., 2020), transport usage varies depending on the change in land use and developments within each area. The difference between land uses inside and outside of the LEZ, implies extra daily trips within the LEZ area (interviewee 8). Hence, this variation is not related to the LEZ, which is the same argument raised by the RET expert through e-mails.

Nevertheless, Figure (4.19) shows an acceleration of Metro usage after 2016 (dashed red line: like figure 4.16). This again implies further statistical tests to see whether it is an effect of the LEZ or not and whether it is similar in both graphs before and after or not. Another interesting observation is the major drop in usage in 2020. Mainly due to the COVID-19 crisis, therefore this year shall be excluded from the statistical analysis.

Experts' opinion on the difference in transport usage before and after 2016:

The eight experts agreed that the number of banned cars was not big enough to have a significant impact already. At the same time, based on the Rotterdam senior mobility expert, even if people switched to transportation, the capacity is not ready to absorb that transition.

However, for future developments from the point of view of interviewees 4,5, 6, and 7. If the LEZ is well-linked with good transportation and a good parking system, users will prefer not to take the car into the city. Box 4.14 illustrates the most significant responses.

"… of course, some of the users might switch to the public transport. But I do not think there is big difference, since there were relatively few people that were not allowed to enter the zone." (Interviewee 2)

"…the only good alternative for car is the public transport and especially the Metro... But now, the public transport system is at the maximum capacity. It is full. And that is a big problem. So, we can build more P+R places but the Metro is full." (Interviewee 3)

"I know that many people when they have to go into the inner city of Rotterdam (myself as well) they always park in a parking lot around the city center and make use of public transport…" (Interviewee 5)

Box 4.14 Experts opinion on the current effect of LEZ on publuc transport usage

Based on this data and on the interview feedback, it is obvious how public transport is a major aspect when it comes to LEZ planning. Even though the number of banned cars from the city was not too much, the public transport use is accelerating in Rotterdam (RET, 2020) and that acceleration happened after 2016. This is annual extra transport usage, which must be considered if the network is already full form now (see Chapter 4, 4.4.4.1. infrastructure connections).

4.4.2.2. Active Travel

The initial proposal for this sub-variable was to measure the usage of bikes and to walk. However, after doing the research and based on the interview with the Municipality senior mobility expert, *"It is very difficult to measure the overall walking in Rotterdam. We are making baby steps with measuring pedestrians."* (Interviewee 3). Thus, this sub-variable includes only one indicator, which is "Cycling tips per working day (visual counts in selected locations)."

i. Cycling tips per working day (visual counts in selected locations)

"Cycling plays a prominent role in keeping the city accessible, active, and healthy. Therefore it deserves priority" (Rotterdam, G., 2019, p.38). The map in Figure 4.20 shows 22 visual counting locations, which the municipality uses to evaluate the annual bike usage per working days in Rotterdam. As indicated in the Bike plan 2025 report, the locations are set near the city main streets, center, and outside in busy places. Therefore, it gives a comprehensive indication of bike usage in Rotterdam (Rotterdam, G., 2019).

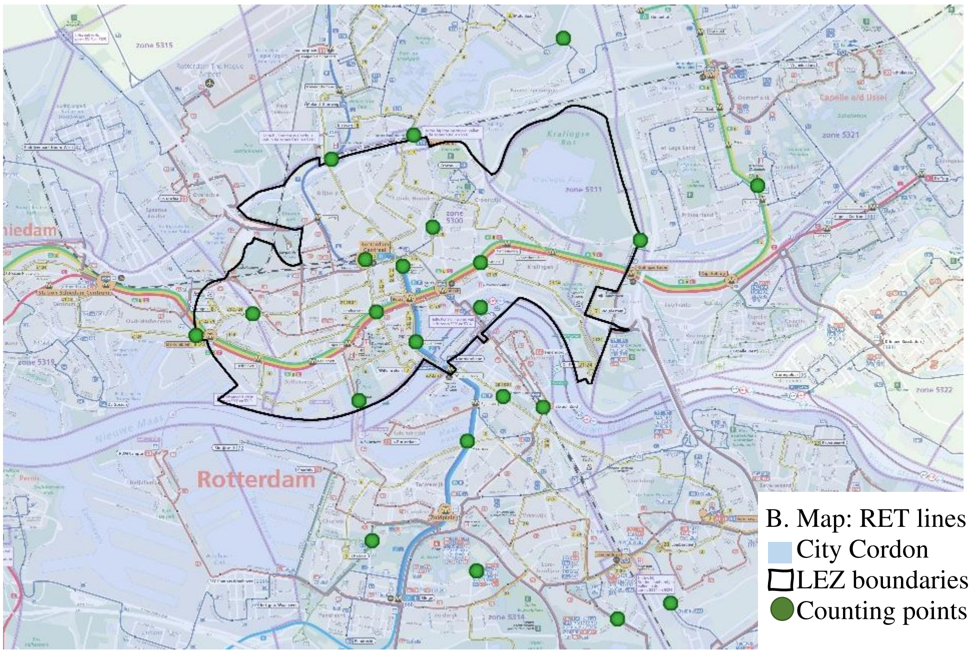


Figure 4.20 : 22 selected bikes counting locations is Rotterdam. Based on (RET, 2020; Rotterdam, G., 2015; Rotterdam, G., 2019)

Figure 4.21 illustrates the number of bike passages through the 22 locations per working day. The year 2020 is estimated based on the natural increase. Figure (4.20) shows a continuous average increase over the whole period. There is a noticeable slight difference between the two years 2017 and 2018, which could be due to the measures applied in the Rotterdam Bikes Plan 2016-2018 (Rotterdam, G., 2016).

To know whether there is a variation in the rate of increase before and after the LEZ, it is required to perform a statistical analysis of means (Chapter 4, 4.4.2.4.).

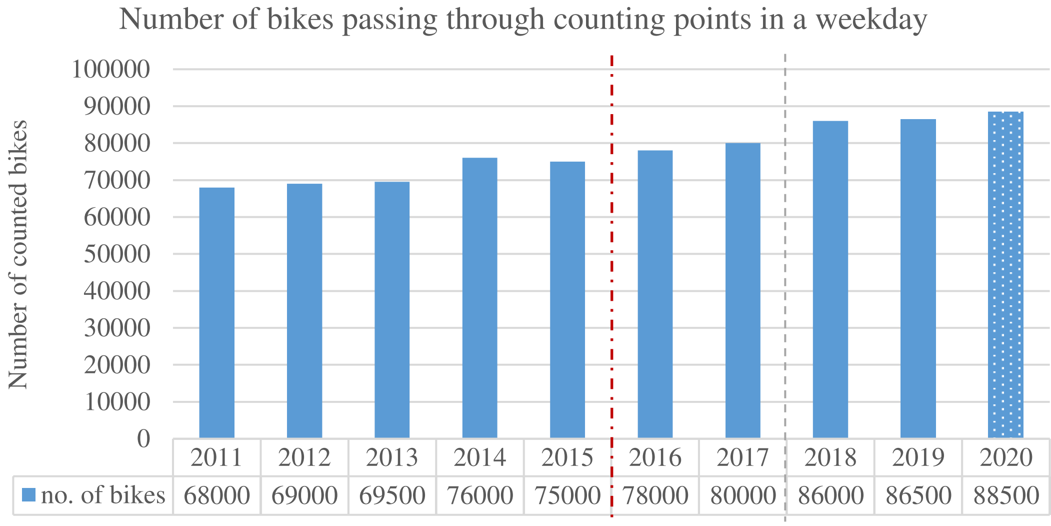


Figure 4.21 : Annual bike counts in 22 selected locations is Rotterdam. Based on (Rotterdam, G., 2019)

<u>Experts' discussion on the status of active mobility in Rotterdam:</u>

The municipality experts talked about the city plans to improve cycling and active mobility. These are currently a priority (Rotterdam, G., 2016; Rotterdam, G., 2019). Since 2016 the city had plans to improve cycling. They planned to replace the short (3-5 km) car trips by bikes. And increase the parking spaces that allow different types of bikes to park (Heuts, 2016).

Yet, in 2020 cycling is still considered as an inadequate means for all users and trips (interviewee 2). Therefore from 2020, the city is taking real actions into providing spaces for different bike users (e.g., Buggies and Cargos) within the city center and the main stations (Puylaert, 2020).

Nevertheless, when asked about the hierarchy of importance of different means of transport, five experts started with active mobility then public transport. The other three experts started with public transport then active mobility. Yet, they explained that there should be no prioritization. Governments should work on the sufficient provision of all means of sustainable transport. On the one hand, it is very important to have an improved cycling infrastructure in the city. On the other hand, as an alternative for the car; public transportation shall be addressed first. Box 4.15 illustrates the above-discussed points from the interviews.

"When we extended the LEZ in 2016, we also worked on improving bicycle and pedestrians. But that was not obligatory a combination it was more separate measures." (Interviewee 1).

"We have a lot of cyclists in Rotterdam, but is it safe for everyone? (Interviewee 3).

"I would say the combination of bikes and a high-quality public transport, those are for the Netherlands, I think, the two most suitable options." (Interviewee 5).

Box 4.15 Active mobility and bikes usage

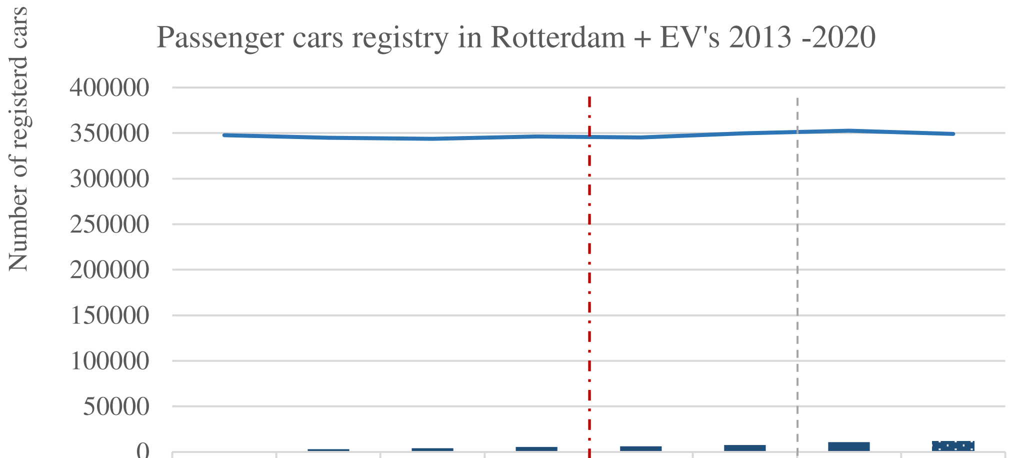
4.4.2.3. E-mobility:

The initial proposition for this sub-variable was to include E-cars and E-bikes. However, for the sake of this research and the time and data limitation, only E-cars will be studied through the two indicators: “annual number of electric passenger cars registered in Rotterdam” and “annual km traveled by electric cars in Rotterdam.”

i. Annual number of electric passenger cars registered in Rotterdam

Rotterdam is promoting the use of electric transport to improve air quality. As in the Air Quality Agenda 2015, the city will be providing more local EV charging points within the package of the LEZ and the Scrappage scheme (Boer and Erdem, 2017; Rotterdam, G., 2015).

Figure 4.22 shows the results of the city’s focus on electric car development. The data started in 2013 as there was difficulty in finding data before 2013. Also, 2020 is estimated based on the normal increase for the statistical analysis comparison.



	2013	2014	2015	2016	2017	2018	2019	2020
EV	1000	2990	3998	5645	6385	7665	10823	11984
total	347700	344700	343700	346400	345300	349600	352600	348900

Figure 4.22 : Overall and EV car registry in Rotterdam. Based on (Gemeente Rotterdam, 2013; Rotterdam, G., 2020)

Out of the overall passenger car registry in Rotterdam, which is almost not changing since 2013, a significant increase in the electric car registry is gradually taking place. Since the LEZ application (dashed red line), the EV is noticeably increasing. In 2019, the number doubled compared to 2016. The highest rate of increase occurred between the years 2018 and 2019. Where after the rate of increase is approximately 1500 E-car per year, from 2018 till 2019, 3000 E-car was added to the city.

ii. Annual km traveled by electric cars in Rotterdam

As for the actual usage of EV in Rotterdam, Figure 4.23 shows the statistics of the emission-free km traveled in the city (Rotterdam, G., 2020).

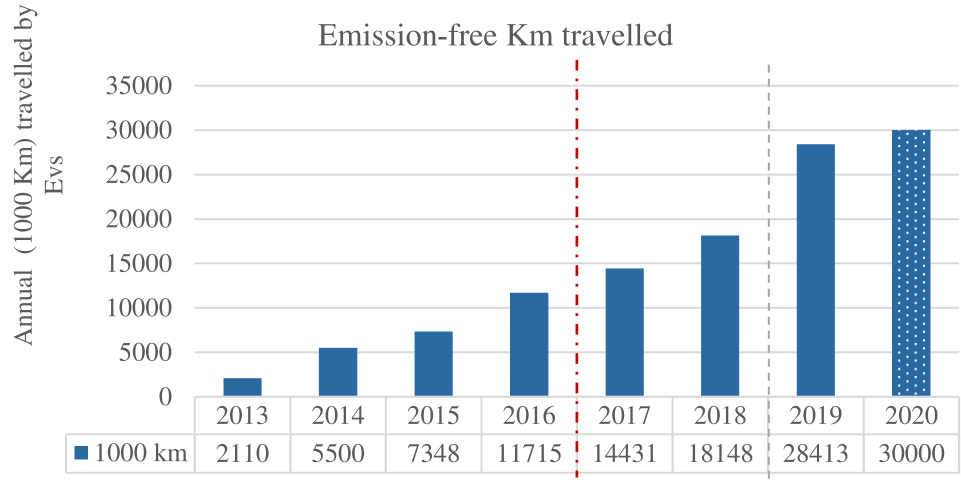


Figure 4.23 : EV km travelled in Rotterdam. city (Rotterdam, G., 2020).

Figure (4.23) shows how Rotterdammers have been increasing their EV usage annually since 2013, with an average rate of around 3 million km increase annually. However, from 2018 to 2019, the number of km traveled has increased by 10 million Km. This comes in line with the data in Figure 4.22 that showed the increase of cars in the same year.

Hence, from these graphs, more detailed statistical tests are required to measure the influence of the LEZ and the traffic plan on the increase in EVs in Rotterdam and to answer that main research question.

<u>Experts' discussion on the status and the future of E-mobility in Rotterdam:</u>

Rotterdam's future vision for clean air is giving big attention to electric mobility "*Stimulating the use of electric vehicles in Rotterdam is seen as a crucial part in improving sustainable mobility and transport in the city." (Van Der Pas, 2015, p.1). However, e*xperts' opinions on the promotion of electric cars as a sustainable replacement for polluting cars were varying.

On the one hand, 3 out of the eight experts discussed the highly polluting embodied energy that EV produces. At the same time, six experts discussed the volume that EV leaves in the traffic. They suggest that it shall not be the main mode for the future mobility. If the overall volume of traffic is still large, then EVs are not a good enough replacement for polluting cars.

On the other hand, two experts discussed their expectations for a more advanced future for EV's (Stamp et al., 2012). A less polluting and a smaller (Figure 4.24) version will be used, and cities must be ready to accommodate that. Box 4.16 illustrates the related quotes.

“As long as you produce electricity with coal, or fossil fuels; an electric car could be even more polluting than a normal conventional car.” (Interviewee 2)

“It makes sense only if it focuses on small E-cars and not the big Tesla's” (Interviewee 6)

“...it takes time, maybe in 10 years from now the production of E-cars will be less polluting. From a viewpoint of the city, I do not think we have to put a lot of extra energy on that. We can better put our energy and thoughts in how to make the city fossil Free.” (Interviewee 3)

Box 4.16 : Experts discussing the future of E-mobility.

Figure 4.24 : Small EV compared to large one in taking half the space required. (Attia, 2020)

Based on the above data, it is obvious how the city is moving towards EVs. First, they are reducing the local air pollution; second, they are building infrastructure for the future. With the hope of future clean electricity, EVs can solve the problem of air quality. Yet, unless people focus on purchasing small E-cars, there will still be a traffic volume issue.

4.4.2.4. Statistical analysis

This section includes the statistical tests applied to answer the second research sub-question. For this sub-question public transport (Figure 4.16) is agglomerated to have an initial idea on the overall usage for before and after the LEZ. Bikes are used as presented in Figure 4.21. While data on the EV km traveled (Figure 4.23.) will be used, for the years 2011 and 2012 in EV km, the numbers are estimated with a similar ratio to the electric charging points (See infrastructure connections).

Data from the first research sub-question on the LEZ variable (indicator: Number of cars entering the three city boundaries per year, Figure 4.8.) will be added to the analysis. To have a standpoint to which the state of usage of alternative modes of transport can be compared.

i. Independent sample t-test

To test the difference in the state of usage of modes of transport before and after 2016, an independent sample t-test with a 95% confidence interval is suitable. The test is expected to show whether there is a change in the variation for each mode before (2011-2015) and after (2016-2020) the LEZ or not. Therefore, the test is applied to each dataset of the number of trips per working; Cars (3 zones), bikes, public transport, E-cars (km traveled) individually.

Table 4-2 Independent Samples Test. SPSS analysis results.

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
All cars	Equal variances assumed	1.01	.343	-4.40	8	.002	-8970.0	2035.7	-13664.3	-4275.6
	Equal variances not assumed			-4.40	7.25	.003	-8970.0	2035.7	-13749.7	-4190.2
Ring cars	Equal variances assumed	.22	.645	-1.49	8	.174	-1701.2	1138.6	-4326.9	924.5
	Equal variances not assumed			-1.49	6.94	.179	-1701.2	1138.6	-4398.2	995.8
Center cars	Equal variances assumed	11.08	.010	.56	8	.587	526.2	929.2	-1616.5	2668.9
	Equal variances not assumed			.56	4.29	.599	526.2	929.2	-1984.3	3036.7
Bikes	Equal variances assumed	.66	.439	-4.69	8	.002	-12300.0	2620.1	-18341.9	-6258.0
	Equal variances not assumed			-4.69	7.69	.002	-12300.0	2620.1	-18383.8	-6216.1
Trans port	Equal variances assumed	.02	.890	-5.62	8	.000	-65596.8	11671.7	-92511.9	-38681.6
	Equal variances not assumed			-5.62	7.83	.001	-65596.8	11671.7	-92610.5	-38583.0
Km e-cars	Equal variances assumed	11.60	.009	-4.37	8	.002	-17078386.4	3900008.4	-26071821.9	-8084950.8
	Equal variances not assumed			-4.37	4.92	**.007**	-17078386.4	3900008.4	-27151709.5	-7005063.2

The results in table (4.2.) show that between the variances of the two periods of study, a highly significant change occurred to the number of km traveled by E-cars, while no significant change occurred to any of the car cordons or the public transport or bikes (Levene's test proved equality of variances).

4.4.2.5. Conclusion

In conclusion, to answer this sub-question. On the one hand, the results show that over the past ten years there is a gradual increase in the usage of all modes of transport. Furthermore, within that increase, the usage of E-cars is also gradually increasing. As for the hierarchy of transport, the results showed the dominance of the metro system over all other transport modes. Where, most of the metro usage is concentrated within the LEZ boundaries for land use reasons.

On the other hand, the city is taking steps into improving the public transport network and reducing the inner traffic. For now, the public transport network is at its maximum capacity. Thus, the increasing number of travelers is leaning towards road traffic since Rotterdam is characterized by its strong road traffic network. This a challenge the city is facing, especially after the LEZ policy withdrawal and the plans to reduce the traffic.

4.4.3. LEZ policy influence on Alternative modes of transport

Through the results of the two variables, *Low-emission zones policy* and *Alternative modes of transport*, this section answers the research sub-question: **"How does the low-emission zone policy measure influence the difference in usage of alternative modes of transport before (2011-2015) and after (2016-2020) the policy adoption?".**

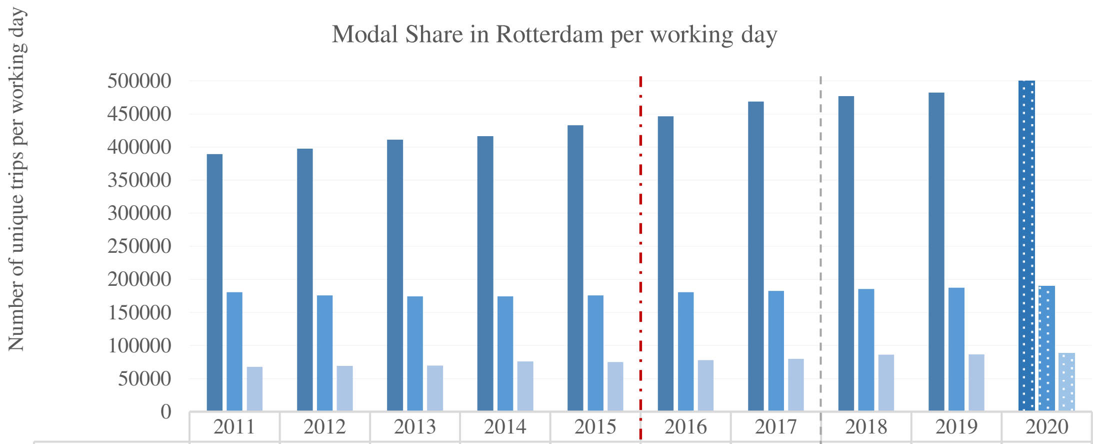
The question is answered through statistical analysis (ANOVA and correlations), interviewee quotes, and the secondary data results for the three sub-variables "Modal share," "electric mobility," and "achieved targets," including 3 of their indicators. Since the second two sub-variables were already discussed in the previous questions, they will be used directly in the statistical tests (4.4.3.2.).

4.4.3.1. Modal Share

To analyze this sub-variable combined data on transport (Passenger cars, Public transport, and cycling) usage per mode will be used, forming the new indicator "annual number of transport trips per mode in a working day," which represented the modal share.

i. Annual number of transport trips per mode in a working day

This indicator compares the average number of daily trips made by cars and bikes and public transport in a working day. Cars and bikes are measured through the visual counting locations all over the city (agglomerated cordon), while the public transport is measured through the RET registered check-ins.



	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Transport trips	389041	397260	410959	416438	432877	446575	468493	476712	482192	500587
Car trips	180814	175971	174356	174356	175971	180814	182428	185657	187487	189931
Bikes	68000	69000	69500	76000	75000	78000	80000	86000	86500	88500

Figure 4.25 : Modal Share in Rotterdam per working day. Based on (RET, 2020; Rotterdam, 2019a; Rotterdam, 2019b)

Figure 4.25 illustrates the Modal share in Rotterdam. The Figure proves that there is a dominance of public transport usage in the city. Where since 2011, the public transport trips are almost double the car trips. In comparison, bike trips are even less than half of the car trips.

Since 2017 the public transport trips reached its highest rate of increase (around 22,000 more trips in one year). Along with that increase, car trips have been decreasing from 2011 till 2015. However, starting from 2016, it increased again and kept gradually increasing until 2019. As for the bikes, there is an almost constant increase over the ten years. More details on this Figure's variation in the difference will follow section 4.4.3.2.

It is important to note that, due to the lack of data, public transport includes the overall RET area (RET, 2020). While cars and bikes passages include location inside the city agglomerated cordon. Furthermore, the car trips assume one user per car, as there is no data on the number of passengers per car in Rotterdam. Hence, results might differ if the same zones and unique passengers are compared. However, the results are still reliable as an overall average, since these are the only data sources available which give an indication of the overall usage.

Experts' opinion on the influence of LEZ on Alternative modes of transport:

The city of Rotterdam is aiming at decreasing the share of polluting trips by improving transportation, adding parking restrictions, and providing better active facilities (Heuts, 2016; Rotterdam, G., 2017). Based on the 5 Rotterdam interviewees' responses, the city did not plan on that as a necessary measure to be coupled with the LEZ. It was more of a different approach that came within the short term mobility agenda 2015-2018 (Rotterdam, G., 2015).

However, based on the discussion with interviewee 2 and 3, with the drop of the LEZ, the city realized the need to accelerate that approach and to make it of a long term to be more realistic (Box 4.17.). Therefore, they introduced the 2017-2030+ Rotterdam traffic plan (Rotterdam, G., 2017).

> *"The new city council decided to take measures for less motorized traffic in the city as a more structural approach… Because we skipped the LEZ for passenger cars and vans and to reduce the amount of traffic. We are giving now extra effort for improving cycling, pedestrians and other alternatives…"* (Interviewee 1)

Box 4.17 Discussion on the need for improving alternatives.

Rotterdam is characterized by being a hub for different modes of transport, yet it can still be considered (based on its history of and urban tissue), one of the most car-oriented cities in the Netherland (Berkers et al., 2019). Hence, it is difficult to predict or control the future change in modal shares in such a large city. Yet, and based on the discussion with 5 of the interviewees, there can be actions taken to stimulate the move towards a certain direction, but there will always be a need for modal share and variation of modality (Box 4.18.).

*"The mobility behaviour of people has changed over the years, and the same person also change his or her mobility behaviour every day, different times per day. So, during the day and during the week, people vary between means of transport… I do not think you can identify a priority because it is so complex. If you identify a priority, you forget too many things." (*Interviewee 2).

"…Rotterdam policymakers still have the idea that a city like Rotterdam should be accessible for all modes of transport…" (Interviewee 5)

Box 4.18 Discussion on the modal share in Rotterdam.

From the above data, it is proved that from the beginning, the city did not plan on changing the modal share distribution as an effect of the LEZ. However, after the removal of the LEZ, more strict measures are being considered, to first improve the alternatives, increase the awareness then reduce the traffic volume in the city centers specifically (Rotterdam, G., 2017).

4.4.3.2. Statistical Analysis

To test the influence of LEZ on the difference in the usage of different modes of transport, and to follow up on the previous data results. ANOVA tests are performed among the data on the different modes after 2016. Later, based on the ANOVA results and on the previous t-test results (Section 4.4.2.4.) for the EVs, a correlation took place to show whether there is a relationship between the ANOVA variation in the difference or not.

The provided data sets for public transport (bus, tram, metro) and bikes account for one user per trip, while for the cars, it is not clear how many passengers are in each trip, therefore the assumption for the ANOVA will be based on one user per car trip.

i. Analysis of variance (ANOVA)

For this question, different modes in public transport is separated and compared (Bus, tram, metro), to know which mode of transport is affected the most.

Table 4-3 : ANOVA test between different modes (bus, tram, metro, bikes, 3 cars cordons)

ALL POINTS					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	162046037585.805	6	27007672930.968	789.918	**.000**
Within Groups	957333145.671	28	34190469.488		
Total	163003370731.477	34			

The ANOVA in Table 4.3. showed a significant difference between the variable's variations after 2016. Thus, a more detailed analysis between groups is required to identify the source of that significance (multiple ANOVA comparison).

ii. Multiple ANOVA comparison

The multiple comparison in Figure 4.26 (See annex 4 for detailed table) proved the significance of variation within all variables except for the “bus” and the “bikes” together. Where they seem to have closely related turnovers, hence Pearson’s correlation will take place to identify the relationship between the change in variations.

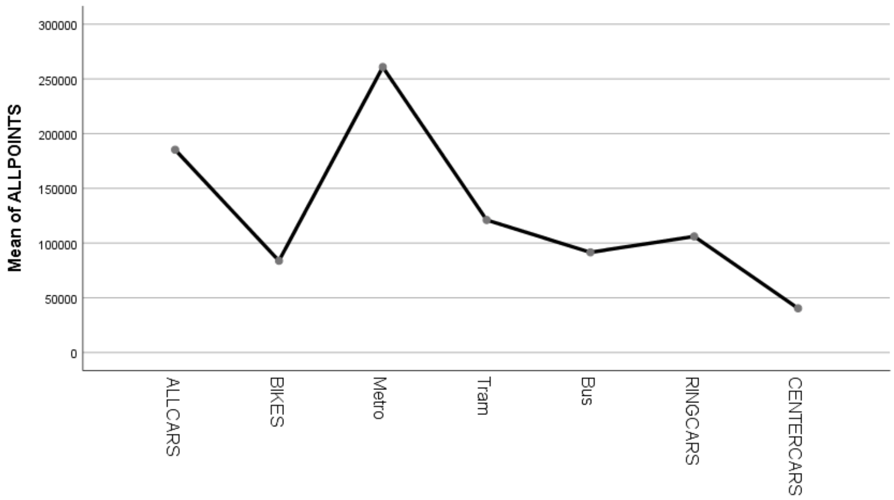


Figure 4.26 : Mean of all points per transportation Mode

iii. Pearson’s Correlation

Pearson’s correlation is appropriate for raw data on two linear continuous variables. Hence, it is suitable here between the different modes change, to know the extent of the LEZ effect on the previously proven variations.

Table 4-4 : Pearson’s correlation

		Bikes	Metro	Tram	Bus	EV_KM	All Cars	Ring Cars	Center Cars
Bikes	Pearson Correlation	1	.959**	-.119	.941*	.901*	.974**	.824	.882*
	Sig. (2-tailed)		.010	.849	.017	.037	.005	.086	.048
	N	5	5	5	5	5	5	5	5
Metro	Pearson Correlation	.959**	1	-.074	.968**	.936*	.964**	.886*	.962**
	Sig. (2-tailed)	.010		.906	.007	.019	.008	.045	.009
	N	5	5	5	5	5	5	5	5
Tram	Pearson Correlation	-.119	-.074	1	.118	-.164	-.032	.109	.099
	Sig. (2-tailed)	.849	.906		.850	.792	.960	.861	.875
	N	5	5	5	5	5	5	5	5
Bus	Pearson Correlation	.941*	.968**	.118	1	.840	.929*	.947*	.930*
	Sig. (2-tailed)	.017	.007	.850		.075	.022	.015	.022
	N	5	5	5	5	5	5	5	5
EV_KM	Pearson Correlation	.901*	.936*	-.164	.840	1	.961**	.669	.945*
	Sig. (2-tailed)	.037	.019	.792	.075		`1.009	.216	.015
	N	5	5	5	5	5	5	5	5
All Cars	Pearson Correlation	.974**	.964**	-.032	.929*	.961**	1	.771	.946*
	Sig. (2-tailed)	.005	.008	.960	.022	.009		.127	.015
	N	5	5	5	5	5	5	5	5
Ring Cars	Pearson Correlation	.824	.886*	.109	.947*	.669	.771	1	.815
	Sig. (2-tailed)	.086	.045	.861	.015	.216	.127		.093
	N	5	5	5	5	5	5	5	5
Center Cars	Pearson Correlation	.882*	.962**	.099	.930*	.945*	.946*	.815	1
	Sig. (2-tailed)	.048	.009	.875	.022	.015	.015	.093	
	N	5	5	5	5	5	5	5	5

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

For the LEZ to have affected the difference in the usage of the modes of transport, a negative correlation must occur between any of the car cordons with the affected mode. The results proved significant positive correlations between the increase of car usage in the "overall city" cordon and the "city center" cordon with the increase of "bikes," "metro," "busses" and "E-cars" usage. While the "ring cordon" only correlates with the "metro" and "busses." As for the "trams," they do not correlate significantly towards any of the variables.

These correlations mean that there is no specific effect for the LEZ on the increase of public transport, bike usage, or E-cars. Since most variables increase relatively, the user's population is increasing, not shifting towards one mode on account of the rest. The increase within the modes is probably caused by other effects (e.g., increase of city users, development ...).

4.4.3.3. Conclusion

In conclusion, Rotterdam proved its strong dependence on the variety of transport modes. There is a constant annual increase in the city travelers. This increase in not correlated with the LEZ and is not favoring a specific mode. Hence, the LEZ has no specific effect on the alternative modes of transport.

Furthermore, the LEZ only acted as a fleet replacement strategy for the sake of air pollution. The policy from the start did not intend to decrease the traffic volume. If that continued, there will be a serious future traffic problem. However, the policy withdrawal has switched the attention of the policymakers towards the need for decreasing the road traffic. For which, a new long-term strategy was adopted (Rotterdam traffic plan).

4.4.4. Rotterdam traffic plan influence on alternative modes of transport

Through the results of the two variables, Rotterdam traffic plan and alternative modes of transport, this section answers the research sub-question **"To what extent do the different measures in the Rotterdam traffic plan influence the user choice of modality before (2013-2016) and after (2017-2020) the implementation?"**

The question is answered through statistical analysis (t-test, ANOVA and correlations), interviewee quotes and the secondary data results for the six sub-variables "Infrastructure connections," "P+R system," "promotional campaigns," "modal share" and "electric mobility" including 8 of their indicators. Since the last three sub-variables were already discussed in the previous questions, they will be used directly in the statistical tests. Hence, the following section is mainly focused on the Rotterdam Traffic plan 2017-2013+.

4.4.4.1. Infrastructure connections

In the traffic plan of 2017, the city included different types of infrastructure connections that are linked to the air quality vision and to decreasing the inner-city traffic (see section 4.2.3). However, most of these plans are still under construction, Figure 4.27 (e.g., the Coolsingel and the regional connections).

Figure 4.27 : Coolsingel construction. Image credits: Adriaan van Dam. (Treebuilders, 2020)

Therefore, for this section, results on the infrastructure projects that are already processed will be presented, through the three indicators "annually added public electric charging points," "public transport coverage, provision and pricing," and "public transport quality and annual disruptions." Since the traffic plan started 2017, comparisons are made for the period 2013-2020 to make a 4:4-year comparison (the 2020 data is assumed for that purpose).

i. Annually added public electric charging points

Under the 7th policy decision in the traffic plan comes a decision for increasing the public electric charging points along with incentivizing the purchase of E-cars (Rotterdam, G., 2017).

Figure 4.28 shows a gradual increase in charging points in Rotterdam since 2013 (Rotterdam, G., 2020). The city made its largest jump of 650 added points in 2013. Later, and since then, there is an average of around 250-300 added points per year. This slightly changed from 2015 to 2016, where the added points reached 374 in one year. The provided numbers only include the public charging places, while the private points have reached around 500 spots by 2018 (Rotterdam, G., 2019).

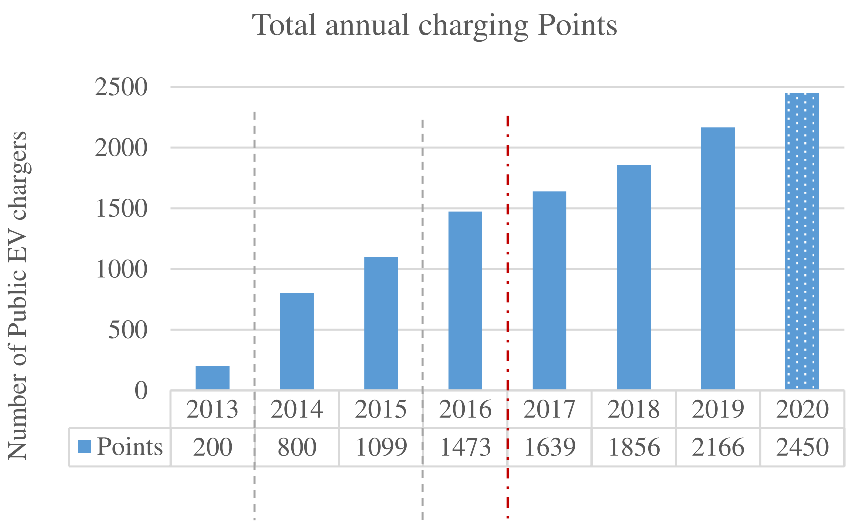


Figure 4.28 : Increase in number of public charging points for E-cars. Based on (Rotterdam, G., 2019; 2020; Van Der Pas, 2015)

Furthermore, Figure (4.28) does not show any significant acceleration in the increase after 2017, which can be explained from the discussion with interviewee 1, where he indicated that the approach for EV increase started before the 2017 traffic plan "*We had a policy for improving electric cars before 2016*", which was also mentioned in different newspaper articles since 2015 (Van Der Pas, 2015).

<u>Government's stimulation and information provision approach:</u>

From the discussion with the municipality experts as week as the Rotterdam electric mobility plan, it is shown that Rotterdam has been working on creating a balance between supply and demand, where they stimulate the demand by providing the needed facilities (e.g., Priority for parking, incentives, and chargers) (Rotterdam, G., 2019). Along with a promotion for the clean environment transition, these measures act as a strong support for the transition towards EVs (Held and Gerrits, 2019).

Figure 4.29 : EV street parking facilities

Based on three of the Rotterdam experts, the city is moving towards the electrification of passenger vehicles to match the demand. Yet it is considered a slow movement that is bound by the market prices and the user demand. Box 4.19. illustrated the above-discussed arguments from the interviews.

> *"It's really difficult for people to switch without knowing that they will find an implemented electrical equipment"* (Interviewee 7).
>
> *"It's very difficult to say about the speed that in which EVs are evolving. For the users, it still depends on the prices".* (Interviewee 3).

Box 4.19 Challenges for the transition towards EV's

ii. Public transport coverage, provision, and pricing

Rotterdam has five metro lines, ten tram lines, and over 77 bus lines that ranges between different frequencies, lengths, durations, and relationship with the city (see figure 4.30). The idea of bus lines is to cover locations and time periods as much as possible and to assure the total coverage and accessibility for the Rotterdam area. Therefore along the year, the bus lines kept changing, and different connection was introduced (OV Netherlands, 2020).

Buses form the minimum share of public transport trips (RET, 2020), and their extension mainly depends on different companies (OV Netherlands, 2020). Hence, the bus lines extensions plan is not taking priority in the traffic plan (Rotterdam, G., 2017).

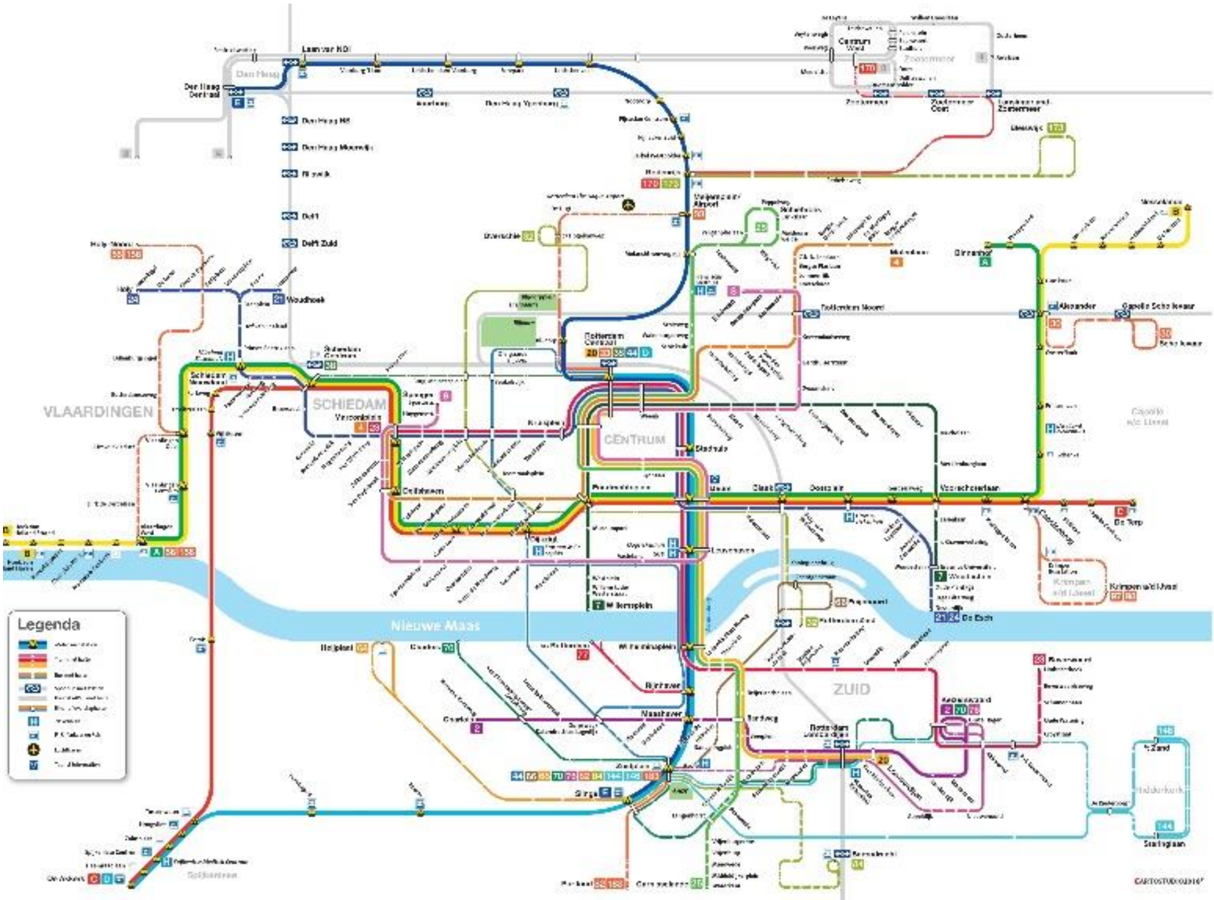


Figure 4.30 : Rotterdam’s transport lines (RET, 2020)

According to the dataset received from the RET concession management advisor, for the metro and tram, the length of lines has been constant at 199 and 194 km, respectively, from 2013 until 2018. In 2019 a new Metro line “the hoekselijn” was introduced to make the overall metro coverage 223 km with an extra eight stops.

This hoekselijn project started its early plan in 2012, and from 2017 to 2019; the actual implementation took place. In September 2019, the project was ready to be used. In addition to that, the city is currently working on a two stations extension for this line, and it is expected to be opened by 2022 (HoekseLijn, 2020).

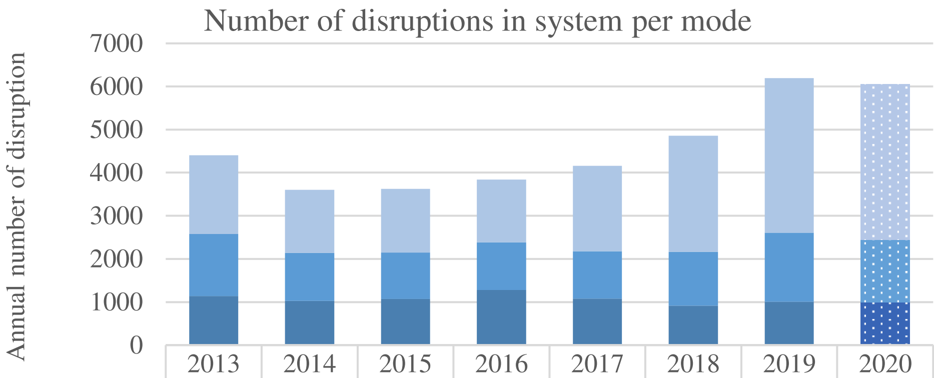
As for the operating hours of the public transport, the system was fixed from 2013 till 2018 at (19:00 hrs. bus, 18:30 hrs. tram and 18:45 hr. metro) per working day. In 2019 they increased the metro operating hours to be 19 hours per day starting from 5:30 am.

While for the public transport pricing in Rotterdam, users get charged by km, while the km price started at (€ 0.132) in 2013, it kept increasing gradually by an average of € 0.002 per year until 2018. In 2019 and after the new line development, prices were raised to € 0.147/ km.

iii. Public transport quality and annual disruption

Another important aspect of the analysis of the city's public transport system is the quality of the system. Figure 4.31 shows the annual number of disruptions occurring to the system. After a gradual decrease in the overall system disruption from 2013 to 2015, the numbers started to increase from 2015.

In 2019 the system reached a peak of 6196 disruption per year. According to the RET website, this is mostly occurring in busses due to the old bus fleet, which is planned to be substituted by a new electrical one in the 2020 plan. At the same time, the cause for the metro and the tram disruptions is the increase in technical defects and material shortages (RET, 2020).



	2013	2014	2015	2016	2017	2018	2019	2020
Bus	1823	1467	1472	1457	1981	2691	3589	3600
Tram	1443	1111	1078	1109	1093	1247	1605	1450
Metro	1135	1026	1073	1277	1082	916	1002	1000

Figure 4.31 : Public transport, Annual number of disruptions in system per mode. (RET, 2020)

<u>Experts' discussion on the quality and the sufficient provision of public transport:</u>

The municipality experts indicated that, while the city is working hard on increasing the public transport provision and quality, effective projects such as the proposed ones in the traffic plan take a long time to be realized. From this and from the above data, it is shown how Rotterdam still needs more improvements for the public transport system in order to keep up with the current transition and absorb the users' shift from cars (Box 4.20.).

> *"…the speed of planning for public transports is going very slow. A new system takes 5, 10, 15 years to be realized. So, the actions now are very small… So that is the big question now, is how to accelerate improvements in public transport."* (Interviewee 3)
>
> *"when public transport becomes something easier, safer and natural, then people will automatically stop thinking of buying cars"* (Interviewee 6)

Box 4.20 Rotterdam public transport improvement

4.4.4.2. Park and Ride system

This sub variable requires both data on the P+R parking usage and the link between P+R and the transport rides. Since the second research question provided data on the transport usage specifically at the selected 14 metro P+R stations, this section will provide the Parking usage in the same stations using the indicator “number and usage of P+R parking spots per year in a working day.”

i. Number and usage of P+R parking spots per year in a working day

Based on the datasets received from the municipality, Rotterdam has had the P+R system since around 1998. Figure 4.32 shows that within and nearby the city boundaries, 32 P+R exists. Out of them, only nine exists inside or exactly at the border of the ring road cordon (RET, 2020). The provided map shows the ensignship of these P+R stations with the city and the LEZ boundaries. Within the presented map, the blue circles represent the 16 stations included in this research (Based on the acquired data).

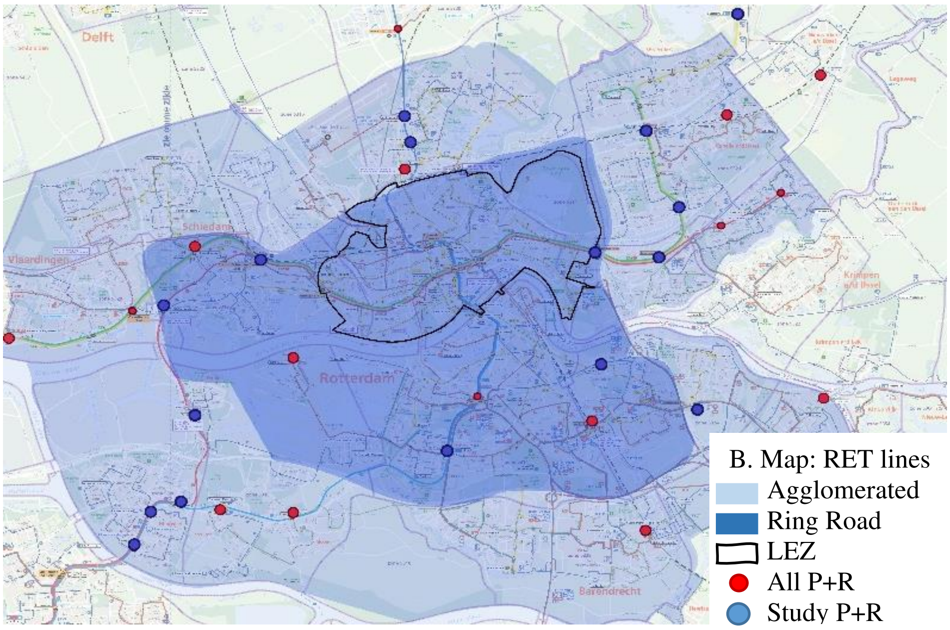
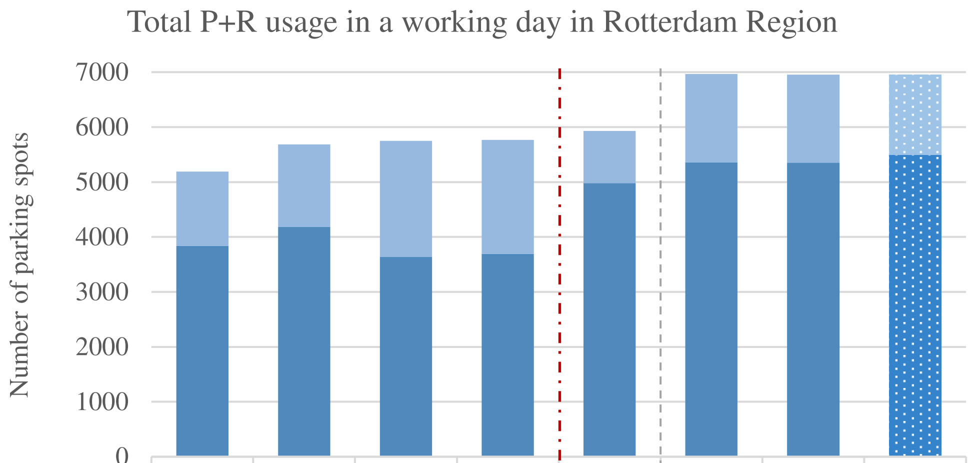


Figure 4.32 : City Map of Rotterdam showing the different zones and P+R places (RET, 2020; Rotterdam, 2015)

The sufficient provision of P+R was included in both the Air Quality Agenda and the Rotterdam Traffic plan. During making the decision for the LEZ boundaries, decisionmakers chose to link the LEZ with the “Krallingse zoom” P+R directly, since it is the closest one to the Ring road entrance (interviewee 1) (Rotterdam, G., 2015; 2017).

Figure 4.33 shows the development of the parking spaces provision and use since 2013. Based on an annual one-day count. The Figure shows the aggregated overall usage of the provided P+R. Based on the surrounding land use, it might happen that some stations are 120% occupied while others are 40% occupied (Kinigadner et al., 2020).



	2013	2014	2015	2016	2017	2018	2019	2020
Free	1349	1501	2105	2071	946	1613	1605	1456
Occupied	3839	4185	3642	3694	4982	5356	5351	5500

Figure 4.33 : Use of P+R places on a working day in Rotterdam Region. Data acquired from the municipality.

For the period 2013-2016, the graph shows a variation in occupancy averages between 3600-4200, where the overall capacity is between 5200-5800. In 2017, an increase of usage by around 1300 spots occurred, without a significant change in the provided capacity. Therefore, starting from 2018, the city provided approximately 1000 extra spots all around the different locations. However, compared to 2017, there is barely any noticeable change in 2018. Furthermore, the occupancy has been fixed for 2018 and 2019 at around 5300 per day.

Experts' opinion on the P+R system:

From the side of the city, the P+R system is encouraged as a step towards decreasing the inner-city traffic. However, four out of the eight experts doubted its success in that regard so far. Since the increase in P+R stations, was not accompanied by a decrease in the inner-city parking spots. The same idea was brought to discussion in 2013 through a study done on P+R usage in Rotterdam (Mingardo, 2013).

> *"The issue is that as long as they are used as additional parking capacity for the old city does not really help…If you really want to get people out of the car, then you have to take out a parking place from the city center."* (Interviewee 2)
>
> *"…it was the basics to make the improvements in the inner city. Because when we built our P+R places we could reduce the street parks in the inner city. So, first alternative and then we can do the stuff in the city itself."* (Interviewee 3)

Box 4.21 Experts opinions P+R on ways to reduce car traffic in the city center

While the municipality experts indicated an indirect reply for that, stating that "to start reducing the inner-city parking and traffic, it was important to provide the P+R in advance". They expect that the P+R will be used even more after the finalization of the inner-city plan. Box 4.21. shows the different interviewee responses regarding the P+R planning.

To conclude, the provided data shows an increase in the P+R usage after the 2017 widening plan. However, the link between the use of the parking spots and the transport usage is doubted. On the one hand, the data results imply further analysis in SPSS. On the other hand, results from this study are still doubted as there is no actual data to link the use of public transport with the parking spots.

4.4.4.3. Promotional campaigns

To measure this sub-variable, qualitative data from the interviews, the traffic plan, and online sources will be providing information on the indicator "Provision of information and user inclusion strategies."

i. Provision of information and user inclusion strategies

As viewed in research sub-question 1, Rotterdam provides the sufficient information on projects through street signage and online websites. The same strategy is applied to the traffic plan measures. In addition to that, the city also provides information-days within the opening or before announcing the start of any project. These information-days takes place at every project location. They are announced online or through mail letters (Figure 4.34) to the concerned residents and companies. They also provide all the details on each project on the website of that project (HoekseLijn, 2020).

The existing stations Maassluis and Maassluis West will be converted into a metro stop. In the Burgemeesterswijk the new Maassluis Steendijkpolder stop will be located.

Information evening 23 September 2013

The Hoekse Lijn project organization is currently working on the first plans in close consultation with the municipality of Maassluis. Because the Hoekse Lijn project is an extensive project, we thought it would be good to catch up with you. We cordially invite you to an information evening:

Figure 4.34 : Example of an information evening invitation (HoekseLijn, 2020).

As for the newly inserted structure of electric charging, parking spots, and P+R, this information is instantly updated and provided through (1) mobile applications, (2) municipality and private companies websites, (3) road signage (Figures 4.35 & 4.36).

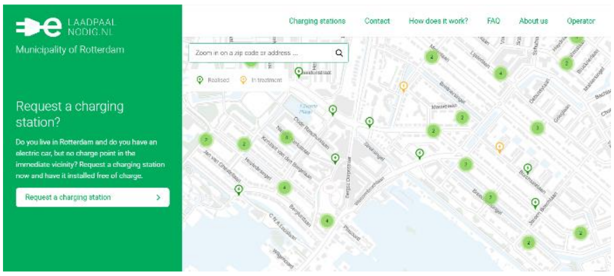


Figure 4.36 : E-charging locations (aanvragen, 2020)

Figure 4.35 : P+R capacity updated signage.

<u>Experts' opinion on the government's information provision strategies:</u>

The eight experts supported this early and continuous information provision. While at the same time, they also called for the need to talk to people about the idea behind the transition to make the decision come from the awareness for both the problem and the solution (Box 4.22.).

> *"First of all, awareness raising. That is the key to create support for this kind of measures. So, inform the audience, what is the air quality? What is the situation of the air quality? Make advertisements on that."* (Interviewee 5)
>
> *"when you start that story, five, seven years in front, people can work to that date…"*

Box 4.22 Experts opinions on the user's inclusion and information provision

From this data, it is shown how the government is working on different scales of awareness-raising and information provision.

4.4.4.4. Statistical Analysis

Based on the provided data in the results section. This section will be divided into two points; 1. to prove the relationship between the charging points with e-cars usage, and 2. P+R with metro and parking usage for the periods (2013-2016) and (2017-2020).

1. The effect of the E-charging points on the use of e-cars and overall car trips:

For this point, the data on the E-mobility will be analyzed before and after 2017, along with different city cordons for all car usage. This analysis work as an attempt to see whether the one-year difference between the LEZ and the Traffic plan application has caused an effect on the variation between before and after or not.

i. Independent sample t-test

An independent t-test (Table 4.5.) is performed to show the change in variation that occurred within each variable individually before and after 2017.

Table 4-5 : Independent sample t-test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Ev spot	Equal variances assumed	.48	.512	-3.522	6	.012	-1134.7	322.2	-1923.149	-346.351
	Equal variances not assumed			-3.522	5.197	.016	-1134.7	322.2	-1953.643	-315.857
Ev km	Equal variances assumed	6.61	.042	-3.730	6	.010	-16079804.5	4311502.5	-26629671.148	-5529937.852
	Equal variances not assumed			-3.730	4.532	**.016**	-16079804.5	4311502.5	-27515708.782	-4643900.218
All car	Equal variances assumed	.00	.926	-4.549	6	.004	-10001.7	2198.5	-15381.423	-4622.077
	Equal variances not assumed			-4.549	5.993	.004	-10001.7	2198.5	-15382.916	-4620.584
Ring car	Equal variances assumed	13.36	.011	-2.795	6	.031	-2647.0	947.2	-4964.734	-329.266
	Equal variances not assumed			-2.795	3.414	.059	-2647.0	947.2	-5464.766	170.766
Center car	Equal variances assumed	2.36	.175	-2.811	6	.031	-907.5	322.8	-1697.557	-117.443
	Equal variances not assumed			-2.811	4.412	.043	-907.5	322.8	-1771.914	-43.086

The results shown proves no significant difference in variation between the two periods in all means, except again in EV Km usage (less significant than in the second sub-question). This means that the rate of increase of charging points was not significantly accelerated after 2017, implying that the traffic plan itself has no direct impact on that. Yet, the results show that the city is increasing the charging spots gradually since 2013. However, users started to use their E-cars more after 2017. Furthermore, the difference in usage of cars along different city cordons is still stable in the two comparisons.

ii. Pearson's Correlations

The following correlation (Table 4.6.) is made for the previous data sets on the periods after 2017, to get a deeper sense of the relationship between the EV usage acceleration and the effect of the added charging points on the overall city car usage within the period of the traffic plan.

Table 4-6 : Pearson's Correlations

		EV_SPOT	EV_KM	ALL_CAR	RING_CAR	CENTER_CAR
EV_SPOT	Pearson Correlation	1	.967*	.984*	.649	.968*
	Sig. (2-tailed)		.033	.016	.351	.032
	N	4	4	4	4	4
EV_KM	Pearson Correlation	.967*	1	.942	.527	.951*
	Sig. (2-tailed)	.033		.058	.473	.049
	N	4	4	4	4	4
ALL_CAR	Pearson Correlation	.984*	.942	1	.767	.909
	Sig. (2-tailed)	.016	.058		.233	.091
	N	4	4	4	4	4
RING_CAR	Pearson Correlation	.649	.527	.767	1	.447
	Sig. (2-tailed)	.351	.473	.233		.553
	N	4	4	4	4	4
CENTER_CAR	Pearson Correlation	.968*	.951*	.909	.447	1
	Sig. (2-tailed)	.032	.049	.091	.553	
	N	4	4	4	4	4

*. Correlation is significant at the 0.05 level (2-tailed).

The table shows a 95% significant correlation between the increase in E-cars charging spots and the increase in E-cars usage. This also is significantly correlated to the increase in the overall car usage in the city. At the same time, the city center car entry has a weak significant correlation with the increase in E-cars usage. Hence, it is proven that within the increase of the electric charging spots, the EV usage increase as well as the overall car traffic.

2. <u>The effect of P+R parking addition on the metro usage inside and outside of the LEZ</u>

From the provided data, there is an intersection of 9 P+R stations that have data on parking usage as well as Metro usage. Thus, the statistical tests will only include these nine stations. To have a closer result, also the comparison between inner-city Metro and outside city metro will only include nine stations inside the city (See annex 3 for selected stations). The stations are selected inside and outside of the LEZ, since within the traffic plan the P+R measure is proposed to be coupled with the LEZ.

i. Independent sample t-test

An independent t-test (Table 4.7.) is performed to show the change in variation that occurred within each variable individually before and after 2017.

Table 4-7 : Independent sample t-test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
METRO IN	Equal variances assumed	3.254	.121	-3.469	6	.013	-11796.000	3400.204	-20115.999	-3476.00
	Equal variances not assumed			-3.469	4.792	.019	-11796.000	3400.204	-20651.827	-2940.17
METRO OUT	Equal variances assumed	4.347	.082	-6.020	6	.001	-8494.250	1411.061	-11946.991	-5041.50
	Equal variances not assumed			-6.020	3.887	.004	-8494.250	1411.061	-12457.149	-4531.35
PR PARK	Equal variances assumed	.229	.649	-8.051	6	.000	-1376.679	170.998	-1795.095	-958.26
	Equal variances not assumed			-8.051	5.833	.000	-1376.679	170.998	-1798.018	-955.33
PR SPOT	Equal variances assumed	.591	.471	-3.690	6	.010	-942.357	255.362	-1567.205	-317.51
	Equal variances not assumed			-3.690	5.146	.013	-942.357	255.362	-1593.225	-291.49

The results show no significant difference between the variation of the two study periods, which means that the traffic plan did not necessarily have an impact on the usage of P+R or metro in the selected stations. However, the following ANOVA will be made to show whether there is any variation of usage among the variables after 2017.

ii. ANOVA

This test is to investigate the variation in differences between the questioned variables after 2017 (Table 4.8.). The ANOVA showed significant variation in variables differences.

Table 4-8 : ANOVA

Change PR					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	19832253376.574	3	6610751125.525	631.370	.000
Within Groups	125645926.199	12	10470493.850		
Total	19957899302.773	15			

The multiple comparison ANOVA (Figure 4.36) proved the variation between all groups except for between the parking spots and the parking use in which it is slightly varying (see annex 4 for detailed tables). Therefore, a correlation will be made to show further relationships.

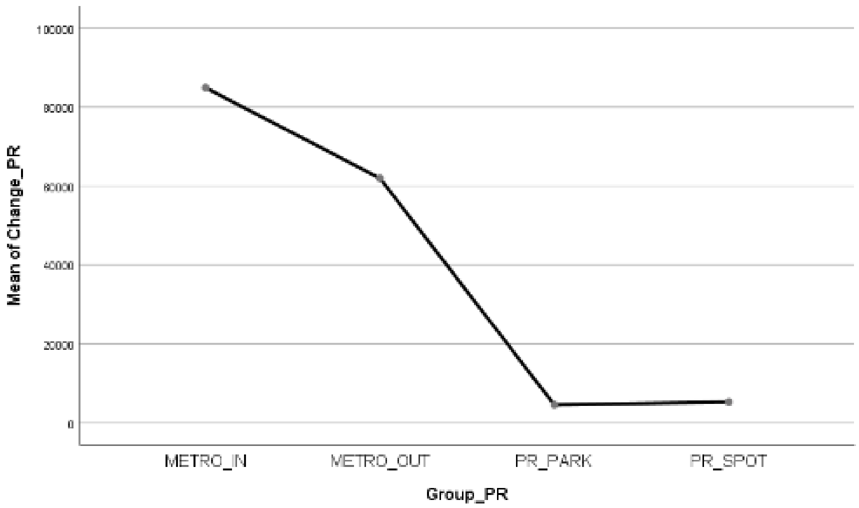


Figure 4.37 : Multiple comparisons ANOVA.

iii. Pearson's Correlations

The correlation in Table 4.9. is done to show whether the increase in metro usage inside and outside of the LEZ is natural of it is different; this if the educed traffic plan policy has an impact, the correlation must be negative.

Table 4-9 : Pearson's correlation

		METRO_IN	METRO_OUT	PR_PARK	PR_SPOT
METRO_IN	Pearson Correlation	1	.971*	.562	.670
	Sig. (2-tailed)		.029	.438	.330
	N	4	4	4	4
METRO_OUT	Pearson Correlation	.971*	1	.714	.822
	Sig. (2-tailed)	.029		.286	.178
	N	4	4	4	4
PR_PARK	Pearson Correlation	.562	.714	1	.964*
	Sig. (2-tailed)	.438	.286		.036
	N	4	4	4	4
PR_SPOT	Pearson Correlation	.670	.822	.964*	1
	Sig. (2-tailed)	.330	.178	.036	
	N	4	4	4	4
*. Correlation is significant at the 0.05 level (2-tailed).					

The results shown prove that transport usage is not affected by the P+R increase at all. Furthermore, the P+R usage is correlated with the increase in P+R spots. Thus, this proves the argument that the P+R acts as an extra parking in the city instead of being a source for the increase in public transport usage inside the city (Mingardo, 2013).

4.4.4.5. Conclusion

In conclusion, Rotterdam is shifting all its attention towards the provision of a strong and consistent sustainable transport system. However, so far, there is no effect on the traffic plan on the user choice for sustainable transportation. On the contrast, the road traffic is increasing, and it is supported by extra parking spots.

Rotterdam's traffic plan is taking a long time to be fully implemented. In order to win the social support, the city is working first on the provision of alternatives before narrowing the streets and/or reducing the inner-city parking. On the one hand, they are providing infrastructure for electric mobility and working on the reduction of the traffic volume. On the other hand, they are strengthening the public transport system and attaching it with a well-structured P+R system. As for the user's awareness, the city is working on the instant provision of information for each policy measure.

This strategy is very tricky, as, in the short-term, it is absorbing more traffic and accepting more polluting cars within the city boundaries. While on the long-term, it is risking another wave of political objections. Hence, there is a need to increase users' awareness and to be more transparent about the future plans. There is also a need to work in parallel, especially to not add extra traffic to the city. Finally, there must be a consistent plan, that either support sustainable road traffic, or shift the users towards public transport and less traffic volume.

Chapter 5: Conclusion and Recommendations

This chapter includes the conclusion and discussion of the data results and analysis to answer each research sub-question. The analysis ends with a final answer for the main research question, which is supported and triangulated with the related literature review. The chapter also discusses policy recommendations based on the conclusions, literature reviews, expert's suggestions, and authors interpretation. Finally, the research limitation and future study needs for the case of Rotterdam is presented as a final section for the chapter.

5.1. Research sub-questions

This thesis has given deep insights on the possible integration of the adopted air quality and traffic policies in Rotterdam in the past ten years. According to (Geerlings et al., 2020, p.12) in their research on air quality policies in the Randstad and the Rhine-Ruhr areas; there is a local gap in policymaking, between the focus "…on policy options and instruments of assessment methods, rather than on decision-making processes and/or implementation issues", where less attention is being given to "aspects of policy integration."

To fill in this gap and build on Geerlings' research and on the previous research done on the effect of the LEZ on air quality in Rotterdam (Boer and Erdem, 2017). This thesis covered four research sub-questions. All set to explain the extent to which the "LEZ policy" and the "Rotterdam traffic plan" influenced the usage of "alternative modes of transport" in Rotterdam.

Sub-question1: This section discusses the first independent variable, **"Low-emission zones policy,"** including its two sub-variables, "Achieved targets" and "Implementation." To answer the sub-question: **What are the achieved targets of the Low-Emission Zones Policy measure in Rotterdam, and how was it implemented?**

Rotterdam introduced the LEZ to contribute to 40% EC emission reduction, reduce the inner-city NO_x concentration through entirely cleaning its old polluting fleet, by the end of 2018 compared to 2015 (Rotterdam, G., 2015). On a short term, the policy was part of the Air Quality Agenda, which by 2017 succeeded in contributing to 36% EC reduction and 16% NO_x reduction, as well as 53% cleaner inner-city fleet (6607 less polluting vehicle crossing the LEZ annually) (Rotterdam, G., 2018). Based on the achieved success in 2017, the LEZ policy was extended on a long-term (2030) as a temporary measure until the city reaches its target (Rotterdam, G., 2017; Stelwagen and Eijk, 2018).

The implemented policy package included different supporting measures that helped to achieve the above-presented targets. Among these measures, the Scrappage scheme was the most supportive and socially inclusive physical measure (used by 5300 users since 2014) (Boer and Erdem, 2017). While on the scale of policy implementation and information provision, the city provided the information through different media sources (road signage, online information, newspapers …) (see Chapter 4, figure 4.10).

With that said, it is important to indicate that the banned vehicles, which annually cross the LEZ, formed only 2.24% of the overall city fleet in 2015 (see Chapter 4, figure 4.5.). Based on that, the policy extension was faced by a huge social-political resistance, which greatly affected its implementation process (Council, 2018). Even though by 2017, the city was proud to have achieved 90% of its 2018 targets due to the combined measures in the Air Quality Agenda, and wanted to extend the policy until 2030, the political resistance lead to phasing out the LEZ. Hence, no further policy evaluation was done in 2020 (interviewee 3). The city then decided on following different measures to achieve its long-term targets, through the provision of alternative transport and strict parking policies (ANWB, 2020; Hope, 2019: Interviewee 1).

These results and policy fluctuation can be explained from the literature, where (Geerlings et al., 2020, p.12) highlighted that the local air quality policies in Rotterdam are characterized by a lack in consistency of targets, stating that "…the adoption of local policy instruments does not incorporate a linear adoption of policy goals, alternatives, alternative evaluation and choosing a particular local policy instruments as they are embedded in large uncertainties…". (See the timeline: Chapter 4, figure 4.2.). While, to solve that (Tobollik et al., 2016, p.8) had talked about the need for data collection and continuous policy evaluations that lead the discussion on alternatives, "…a comprehensive evaluation for the traffic and mobility patterns can lead to illustrate significant aspects.".

Therefore, it can be concluded that the problems faced in the LEZ applications was mostly because of; 1. the inconsistency of the policy, 2. the unclarity of its targets, 3. the absence of communication with the affected people, 4. the small scope of affected cars, which raised doubts on the effectiveness of the LEZ, and 5. the lack of previous preparation and alternatives provision. Based on these, it can be assumed that for the LEZ to be more acceptable and applicable, the city needed to work on solving the social-political arguments. This can be done through including the user in decision making, increasing awareness of the policy targets, having a large enough scope of affected car, and finally providing alternatives that are based on updated data collection and traffic policy evaluations.

Hence, this implies the need to further understand the status of usage of the alternative modes of transport in Rotterdam, which is discussed in the following sub-questions.

<u>Sub-question2:</u> This section discusses the dependent variable, **"Alternative modes of transport,"** including its three sub-variables "Public transport," "Active travel," and "E-mobility." To answer the sub-question: **What is the state of usage of alternative modes of transport in Rotterdam before (2011-2015) and after (2016-2020) the policy adoption?**

Rotterdam, as a hub for different modes of transport, is characterized by a very strong public transport system, especially the metro system (Stratelligence, 2016). By identifying the alternative modes of transport in this question as; public transport, bikes and E-cars, this sub-question studied the status of usage of these modes over the past ten years. The data results proved that within the modes of transport, the public transport always had dominance over the rest of the modes, after which comes the car then the bike (see Chapter 4, Figure 4.25.).

The independent t-test (Chapter 4, Table 4.2.) applied to compare the results of all transport usage over the two periods of study, proved no significant variation between the variances of public transport, bikes, and overall passenger cars before and after 2016. While it showed, a strong significant variation between the E-cars annual km traveled before and after 2016.

As for the modal choices within the public transport usage, the results showed a different variation in modal choices with the dominance of the metro over all other modes. Furthermore, it is observed that the concentration of metro usage is inside the LEZ boundaries. Almost double the number of trips is made within the LEZ boundaries compared to the same number of stations from outside the LEZ (see Chapter 4, Figure 4.19.). However, this variation is similar over the past ten years, which can be due to the distribution of land uses in the city (Kinigadner et al., 2020), which involves extra daily travelers within the boundaries of LEZ. The land-use issue was also raised through e-mail discussions with the RET expert, where he identified that the reason for the transport use variation could be due to the new buildings in the city.

These results were supported by the interviewees' responses, who stated that the LEZ policy did not include a wide range of users, and it did not include any plans to improve public transport and active facilities. Thus, even if the owners switched to different modes, it will not be of a noticeable effect, and there is no extra public transport capacity for that (see Chapter 4, Box 4.14). While on the contrary, EV purchasing was supported by the Scrappage scheme (as a cleaner vehicle), the increase in charging facilities, and the EV parking prioritization (Rotterdam, G., 2015). These supporting measures are considered amongst the strongest measures that work in favor of the E-mobility acceleration worldwide. (Held and Gerrits, 2019).

As much as the increase in EV usage is favorable for the air quality levels, the inner-city traffic is increasing, and this raises a future issue for the city (See Chapter 4, Box 4.16.). Thus, after the policy withdrawal, the city planned to work on the improvement of alternatives and on the reduction of traffic (Rotterdam, G., 2017).

However, based on the experts' discussions and on the literature review, for these measures to succeed, the city needs to consider that 1. Rotterdam public transport system has reached its full saturation capacity, 2. Rotterdam is a car-oriented city (especially for its harbor and its business settings), since its revival and replanning after the bombing 1940, it has been favoring the car use through providing a very good traffic infrastructure (Runyon, 1969). Thus, for normal users, cars are faster, more convenient, and waste less time and effort compared to public transport that sometimes implies 2 or 3 modal shifts within the same trip (Interviewee 8).

Therefore, it can be concluded that, in any future city planning, the above-mentioned points must be taken into consideration. On the one hand, if the city wants to keep following a car-oriented vision, then there must be rigid encouragement towards zero-emission mobility. If diesel and benzene cars of emission classes E4-E6 will be banned in the future, there must be prior awareness-raising campaigns so that people will not be surprised and file more complaints. On the other hand, if the city wants its population to shift towards public transport and to reduce traffic, larger public transport plans (e.g., increase in capacity, frequency, speed, and coverage) must start taking actions early, since it will take years to be accomplished.

Subsequently, to get more insights on the variation within the transport network and to see whether the increase in EV usage affected the rest of the modes or not, the following sub-question analysis the effect of the LEZ on the variation between modes.

Sub-question3: This section discusses the influence of the first independent variable, **"Low-emission zones policy,"** including its two sub-variables, on the dependent variable **"Alternative modes of transport,"** including two of its sub-variables "Modal share" and "E-mobility." To answer the sub-question: **How does the low-emission zone policy measure influence the difference in usage of alternative modes of transport before (2011-2015) and after (2016-2020) the policy adoption?**

One of the expected effects of applying the LEZ is the change in the users' transport mode and behavior. Thus, the policy can be expected to make a difference in the usage of alternative modes of transport (Ellison et al., 2013). However, this difference is bound by the number of restricted vehicles and the type of supporting policies (see Chapter 4, Box 4.14.).

The ANOVA (Chapter 4, Table 4.3.) applied between the different modes of transport (2016-2020), proved strong variation amongst the transport usage. While the Pearson's correlation (Chapter 4, Table 4.4.) showed a significant gradual increase between the usage of all modes of transport. This means that the overall city commuters' population is increasing, and the LEZ has no specific effect on that variation.

These results support the experts' explanations that the policy package was not meant to decrease the traffic, it was only meant to replace the type of vehicles to a less-polluting one (See Chapter 4, Box 4.3.). So, even if some users changed their mode, this type of change cannot be seen in the statistical tests' due to the very small number of replacements (see Chapter 4, figure 4.5.). However, based on the experts' discussion and on newspaper arguments, the idea of accelerating the improvement of alternative transportation and decreasing the inner-city traffic came as a substitution to the LEZ (ANWB, 2020; Hope, 2019: Interviewee 1). Thus, it can be said that the LEZ had an impact on proving Rotterdam's need to improve the alternatives and push the users out of polluting cars towards public transport, active mobility, and/or EVs.

Therefore, it can be concluded that the results highlight the urge to consider the decrease in car dependency to guarantee less congestion in the future. If the traffic kept increasing with the same pattern without being faced by public transport alternatives, the city would not be able to absorb that increase anymore. While, based on Rotterdam's history and urban tissue, the city has a very good and accessible car network, which creates difficulty for a small-scaled policy like the LEZ to have an effect on the use of alternative modes of transport.

Nevertheless, the LEZ can be considered as a fast solution that worked on improving air quality, and it is successful in that manner. Yet, for a more resilient future, the city needs to consider different plans and long-term solutions (e.g., decrease car accessibility and increase public transport provision) that allows variations in modality and decreases the road traffic. Some of these traffic measures were introduced in the Rotterdam's 2017-2030+ traffic plan. To better understand the status of traffic planning and transportation in Rotterdam, the following sub-question studies the effect of the 2017-2030+ traffic plan on the variation of transport usage.

<u>**Sub-question4:**</u> This section discusses the influence of the second independent variable **"Rotterdam traffic plan"** including its three sub-variables, "Infrastructure connections," "P+R system," and "Promotional campaigns" on the dependent variable **"Alternative modes of transport"** including two of its sub-variables "Modal share," "Public transport" and "E-mobility." To answer the sub-question: **To what extent do the different measures in the Rotterdam traffic plan influence the user choice of modality before (2013-2016) and after (2017-2020) the implementation?**

"Travel is a derived demand and not an activity that people wish to undertake for its own sake"(Banister, 2008). In a large city like Rotterdam, the provision of a well-structured, safe, fast, integrated, and competitive alternative is the first step to pull the user towards a modal shift. This step must be accompanied by other measures that will push the users out of the car and decrease the inner-city traffic or make it cleaner (e.g., Park and Ride, decrease the width of streets and more EV infrastructure). Hence, these measures are included under the Rotterdam traffic plan 2017-2030 (Rotterdam, G., 2017). However, large plans like this take a long time to be realized (Interviewee 3). Therefore, this research only discusses short term measures (e.g., P+R and the EV improvements). It also gives insights on the current quality of public transport.

The applied t-tests (Chapter 4, Table 4.5. & 4.7.) comparison between before and after 2017 proved a significant change only for the EV km traveled, which compared to the 2016 t-test (Chapter 4, Table 4.2.) is less significant. Therefore, there is no specific effect on the traffic plan on the use of different modes of transport in 2020.

The ANOVA (Chapter 4, Table 4.8.), and Correlations (Chapter 4, Table 4.6. & 4.9.) results showed that the increase in the use of EVs is correlated with the increase in E-chargers. This means that even though it is not related to the traffic plan dates, the city's usage of E-mobility is growing, without any decrease in the overall traffic. Based on the expert's suggestions, this will form future congestion issues. As for the P+R stations, unfortunately, so far, the P+R parking is only used as extra normal parking in the city, where the increase of spots act in favor of the increase of traffic.

The latter was supported by the experts' discussion and the literature review done on the city where (Mingardo, 2013) had applied a study on the P+R usage in some stations in Rotterdam that showed a negative effect for the P+R spots, where it is absorbing more car usage and is not accompanied by any decrease in inner-city parking (See Chapter 4, Box 4.2.).

Therefore, it can be concluded that the analyzed data and interviews showed that the traffic plan has no rigid or consistent measures that account for the increase in alternative transport usage or reduce the inner-city traffic. So far, the short-term applied measures are rather indifferent and act in favor of the increase of car usage, whether it is P+R or EVs support. While the long-term plans of street narrowing or decreasing the inner-city parking (e.g., the coolsingle plan) is still taking time. Furthermore, most probably, these long-term plans will be faced with a huge social and political resistance once applied since the traffic is increasing without peoples' awareness of these plans.

Thus, this sub-question stresses the need for 1. increasing social awareness and information provision for any future measures that can be affected by the present actions, 2. having a clear and consistent vision where the focus should either be on zero-emission traffic or less car use,

3. accompany any increase of P+R with a decrease in the inner city parking. Otherwise, the traffic plan has negative effects due to its lack of focus and consistency. With the LEZ being removed in 2020, even the increasing traffic is no longer guaranteed to be clean.

5.2. Main research question:

To sum this up and answer the main research question: **To what extent do the "Low-Emission Zones policy" and the "Rotterdam traffic plan" influence the usage of "alternative modes of transport" in the city of Rotterdam before (2011-2015) and after (2016-2020) the implementation?**

"Research on car dependence exposes the difficulty of moving away from a car-dominated, high-carbon transport system, but neglects the political-economic factors underpinning car-dependent societies" (Mattioli et al., 2020, p.1). This statement can relate to the proven research findings very well, where it is proved that so far in the city of Rotterdam, the LEZ and the Traffic plan have no significant influence on the usage of alternative modes of transport.

On the one hand, for the LEZ. It is very hard to reach a sustainable transport transition in a democratic city like Rotterdam without being faced with strong social and political resistance. Even though, the policy had a high level of success in achieving parts of its initial air quality and traffic cleaning targets (See Chapter4, figure 4.4. & 4.6.), social and political conflicts played a major role in bending the path of that policy. Furthermore, the scope of the targeted vehicles was not large enough to significantly affect the usage of alternative modes of transport, nor was the city infrastructure ready to absorb a modal shift (See Chapter 4, Box, 4.14). Hence, there is no significant influence on the LEZ on the use of alternative modes of transport.

On the other hand, for the Rotterdam traffic plan. Rotterdam, as a car-oriented large city, needs time to lead a full transition towards sustainable transportation. The traffic plan, after four years, barely has any effect on the usage of alternative modes of transport. On the contrary, the traffic is highly increasing, and the city is becoming more car-dependent without any control over the type of traffic (See Chapter 4, Figure 4.25.). The traffic increase is significantly correlated with the increased number of parking spots (P+R) (See Chapter 4, Table 4.9.), and with the overall increase in the electric charging point (See Chapter 4, Table 4.6.). These have no relationship with the traffic plan itself (See Chapter 4, Table 4.5. and 4.7.). Hence, there is no significant influence on the traffic plan on the use of alternative modes of transport.

Finally, to conclude, the above-discussed conflicts and negative effects were lead by the following policy deficiencies. (1) The lack of creating sufficient environmental awareness to the users. (2) The small number of affected users, which supported the argument on the possibility of reaching the same targets through different measures. (3) The weakness of preparation to face the transition through the earlier provision of alternatives. (4) the inconsistency of targets and unrealistic timeframes, and finally (5) The absence of continuous monitoring and evidence-based policy evaluations.

In conclusion, Rotterdam is still moving very slow and trying to keep holding the stick from the middle, which is not the best strategy to lead such an important transition.

5.3. Policy recommendations

The following recommendations are based on, 1. the experts advise through ATLAS.ti sub-variables occurrences and relationship network (see Annex 2), 2. Literature reviews, 3. Research results. Recommendations address cities that want to apply the LEZ and reduce their inner traffic.

i. It is important to work on the provision of alternative sustainable modes of transport, prior to the LEZ policy implementation for the city to be able to absorb the transition.
ii. From the start, provide clear reasons, a consistent strategy, comprehensive package, and a long-term vision with social inclusion in policymaking and environmental awareness.
iii. Continuous monitoring and consistent evaluation of the applied policy measures can provide support for the political argument and provide information on the user's needs.

Figure 5.1. illustrates the package of policy measures or the framework that must be applied with the LEZ policy to achieve a balanced system and prevent conflicts and political issues.

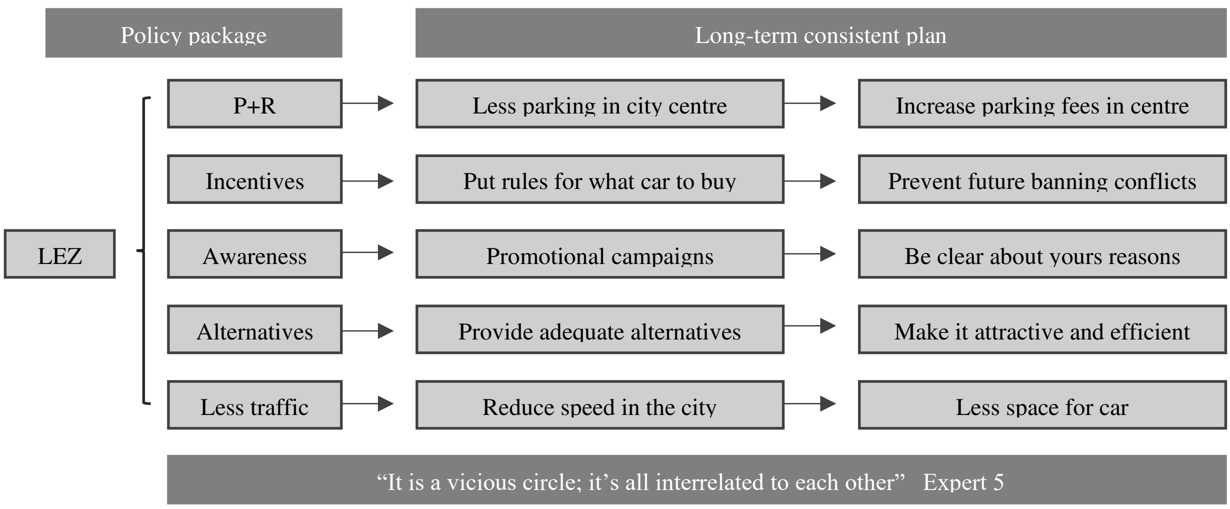


Figure 5.1: LEZ recommended policy package (authors interpretation).

The presented package includes the P+R system, which can be very successful in helping the LEZ only if accompanied by decreasing the parking spots in the inner-city (and/or increasing parking prices), sufficient alternatives, and good connecting-infrastructure. The incentive program also plays an important role within the LEZ package. However, to guarantee fewer future conflicts, this program must be introduced under the vision of a clean future fleet. Where governments inform the program users about the future bans to prevent them from buying vehicles that will be excluded in the future. While to keep track of the inner-city traffic and to prevent the LEZ from allowing more traffic to the inner-city, LEZ must always be accompanied by traffic reduction policies, (e.g., reduce speed and roads width in the LEZ area). Again, this shall be working in parallel with adequate and efficient public transport and active mobility alternatives.

To sum up, the LEZ has always been advertised as an air quality policy. However, in future cities plans and in the European agreements, there are proposed strategies on increasing the LEZ restrictions step by step to includes all polluting diesel and benzene cars. Therefore, it is time for cities to look at LEZ as a car traffic reduction policy as much as it is an air pollution policy. This proposed framework (Figure 5.1.) can act as a step into applying this.

5.4. Research Limitations

The research incorporated different limitations that worked on varying its limit of reliability, and it is very important to work on their improvement to have a clear future vision.

1. Datasets on the usage of different modes do not follow the same measurement conditions; cars are visuality counted once a year, bikes are limited to certain locations, public transport does not have detailed data per station for all modes.
2. The existing datasets on the Municipality is not openly shared with the research community. Furthermore, the municipality evaluation reports are based on different sources, including a 1000 sample surveys (which cannot be significant for a city with 651,446 inhabitants).
3. There is no monitoring stations specified for the LEZ, with continuous counting that is shared with the research community. The TNO had to make a counting week to collect the data for the 2017 report.
4. Due to a shortage of data and time limitations, not all alternative means of transport are included (e.g., shared vehicles, electric bikes, and walking and excluded).
5. Most of the available data is in Dutch, which exerted extra time and effort in the translation and the classification of the documents.

6. Data on 2020 was expected to have an impact, yet due to COVID-19, transport usage was affected. Thus any dataset in 2020 was excluded, and estimated averages are made.

Nevertheless, having these limitations does not lessen the validity of this research, as each dataset used had the same consistent way of measuring along the ten years period.

5.5. Future scopes (Scientific recommendations)

There are local and universal future paths that can be followed by future researchers and decision-makers to cover the gap between the applied traffic policies in theory and in practice.

- Future researchers should seek a universal, consistent, and unified way, or data collection matrix, for measuring and evaluating the usage of different modes of transport. Where transport trips shall be measured by the actual usage of vehicles through the overall km traveled per person per mode. The current approaches which use the number of trips per person or the number of visually counted vehicle are less indicative of the environmental and traffic effects. On the one hand, vehicles can include more than one person, and on the other hand, trip counting does not give an indication of the actual use.
- As for Rotterdam, there is a need for future continuous evaluation and monitoring for any applied or removed policy. It can be expected that after the removal of the LEZ, and with the slow pace of the traffic plan, the city will go back to its previous air quality levels. Different cities in Europe are starting to apply the LEZ, and this can be an opportunity for the Rotterdam citizens to buy the old cars from them (the German second-hand car market is largely open for years). Thus, the annual traffic evaluation is needed to make sure the city is not moving backward.
- Observations with large sample sizes should be made for the city of Rotterdam. This includes surveys and monitoring techniques with a focus on traffic. Similar to the OViN study (CBS, 2020), and the Omnibusenquête survey (Rotterdam, G., 2020), but with a large enough sample to be representative of the transport users.

These are the only way that allows to compare different cities. And to characterize the national and international trends and impacts of the LEZ and traffic plans as an integrated package.

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Annex 1: Interviews Guide

1. Municipality LEZ expert interview

These questions are prepared as a baseline for a master thesis with the title of: “The effect of Low Emission Zones (LEZ) and the Rotterdam traffic plan (2017-2030+) on the use of alternative modes of transport in Rotterdam”. According to this data, a report will be made with the theme of transport and traffic policies in Rotterdam. I think this might be interesting to you, therefore, I promise to send the results by the end of this year, after I finish my MSc.

Background information

1. What are your core responsibilities in the municipality? How long have you been there?
2. What was your responsibilities and role in the LEZ planning?

A. Information on the LEZ:

1. How did you define polluting cars that will be banned from the zone? And what was the (numerical) target of reduction for the number of polluting cars?
2. How did you assign a budget to create the incentive program? What was the budget structure? Was it previously allocated or based on penalties?
3. What was the main reason for phasing out the policy that started in 2018?
4. Based on the learned lessons from the LEZ. What is your recommendation for other cities that are following the same steps?

B. Policy Package “Rotterdam traffic Plan:

5. What explains the behaviour of the people who prefer to pay the LEZ entering fine instead of parking their car outside? And What can be done to change that?
6. How did you reduce the number of polluting cars? And what are the best applied ways for promoting for the LEZ among citizens?
7. To what extent should the governments depend on incentive programs and or/ leave it for the individual awareness?

C. Alternative modes of transport:

8. What is the best and most practical replacement for polluting cars in city centres, e.g. Rotterdam (Bikes – Shared cars – E-bikes – public transit (bus, tram, metro) – E-cars)? And Why?
9. To what extent does the “Low-Emission Zones policy” influence the usage of “alternative modes of transport” in city centres? How? Why?

Is there anything else you want to say regarding the LEZ which you think I need to know? Well, thanks for your time, and If that interest you, I send you the results of my thesis by the end of this year.

2. Municipality Traffic plan expert interview

These questions are prepared as a baseline for a master thesis with the title of: "The effect of Low Emission Zones (LEZ) and the Rotterdam traffic plan (2017-2030+) on the use of alternative modes of transport in Rotterdam". According to this data, a report will be made with the theme of transport and traffic policies in Rotterdam. I think this might be interesting to you, therefore, I promise to send the results by the end of this year, after I finish my MSc.

Background information

1. What is your core specialization? How long have you been in this field?
2. What type of projects did you participate in?

A. EZ planning questions

1. In your opinion, what is the effect of Low-emission zones on the transport emission reduction?
2. Banning logistic vehicles from entering the Low-emission zones had proven its success in emission reduction. To what extent can banning passenger vehicles reach a similar success?
3. What are the best ways of promoting for the Low-emission zones among citizens?
4. To what extent should the governments depend on incentive programs and or/ leave it for the individual awareness?
5. What explains the behavior of the people who prefer to pay the Low-emission zones entering fine instead of parking their car outside? And What can be done to change that?

B. Rotterdam Traffic planning

6. How can we encourage people to abandon the car use in city centers? What communication systems can governments follow to achieve that?
7. The Park & Ride (P+R) is a system that is applied globally with different contexts and types. To what extent do you think it is successful in preventing car usage or increasing transport usage in city centers? And Why?
8. To what extent do you see 'scraping programs' as a way for encouraging car-abandonment?
9. What is your opinion on governments' marketing for electric cars as a sustainable replacement?

C. Alternative modes of Transport

10. How to promote for the use of public transport and active mobility in city centers?
11. In governments approaches for improving mobility. What is the best and most practical replacement for polluting cars in city centers (Bikes – Shared cars – E-bikes – public transit (bus, tram, metro) – E-cars)? And Why?
12. To what extent does the "Low-Emission Zones policy" influence the usage of "alternative modes of transport" in city centers?
13. Based on your experience. What is your recommendation for cities that are starting the policy application?

Is there anything else you want to say regarding the LEZ which you think I need to know? Well, thanks for your time, and If that interest you, I send you the results of my thesis by the end of this year.

3. Mobility and traffic experts' interviews

These questions are prepared as a baseline for a master thesis with the title of: "The effect of Low Emission Zones (LEZ) and the Rotterdam traffic plan (2017-2030+) on the use of alternative modes of transport in Rotterdam". According to this data, a report will be made with the theme of transport and traffic policies in Rotterdam. I think this might be interesting to you, therefore, I promise to send the results by the end of this year, after I finish my MSc.

Background information

4. What is your core specialization? How long have you been in this field?
5. What type of projects did you participate in?

D. LEZ planning questions

14. In your opinion, what is the effect of Low-emission zones on the transport emission reduction?
15. Banning logistic vehicles from entering the Low-emission zones had proven its success in emission reduction. To what extent can banning passenger vehicles reach a similar success?
16. What are the ways of promoting for the Low-emission zones among citizens?
17. To what extent should the governments depend on incentive programs and or/ leave it for the individual awareness?
18. What explains the behavior of the people with polluting vehicles who enter the zone despite if the fine instead of parking their car outside? And What can be done to change that? (Opinion question)

E. Rotterdam Traffic planning

19. How can we encourage people to abandon the car use in city centers? What communication systems can governments follow to achieve that?
20. The Park & Ride (P+R) is a system that is applied globally with different contexts and types. To what extent do you think it is successful in preventing car usage or increasing transport usage in city centers? And Why?
21. To what extent do you see the 'scraping programs' as a way for encouraging car-abandonment?
22. What is your opinion on governments' marketing for electric cars as a sustainable replacement?

F. Alternative modes of Transport

23. How to promote for the use of public transport and active mobility in "city centers" specifically?
24. In governments approaches for improving mobility. What is the best and most practical replacement for polluting cars in city centers (Bikes – Shared cars – E-bikes – public transit (bus, tram, metro) – E-cars)? And Why?
25. To what extent does the "Low-Emission Zones policy" influence the usage of "alternative modes of transport" in city centers?
26. Based on your experience. What is your recommendation for cities that are starting the policy application? And what do you recommend for cities to reduce the inner-city traffic?

Is there anything else you want to say regarding the LEZ which you think I need to know? Well, thanks for your time, and If that interest you, I send you the results of my thesis by the end of this year.

Annex 2: ATLAS.ti results

1. Cooccurrences tables

Table A2.1.: Frequency of intersection between the LEZ and the Rotterdam traffic plan with the alternative modes of transport

Variable		LEZ policy			Rotterdam Traffic plan		
	Sub-variable	Implementation Frequency=63	Political aspects Frequency =42	Targets Frequency =165	Infrastructure Connections Frequency =60	P+R System Frequency =31	Promotional Campaigns Frequency =43
Alter. modes of transport	Active Travel Gr=38	1	1	16	15	5	8
	Modal Share Gr=68	9	4	**43**	**24**	8	5
	Public Transport Gr=55	2	2	**27**	**20**	11	10

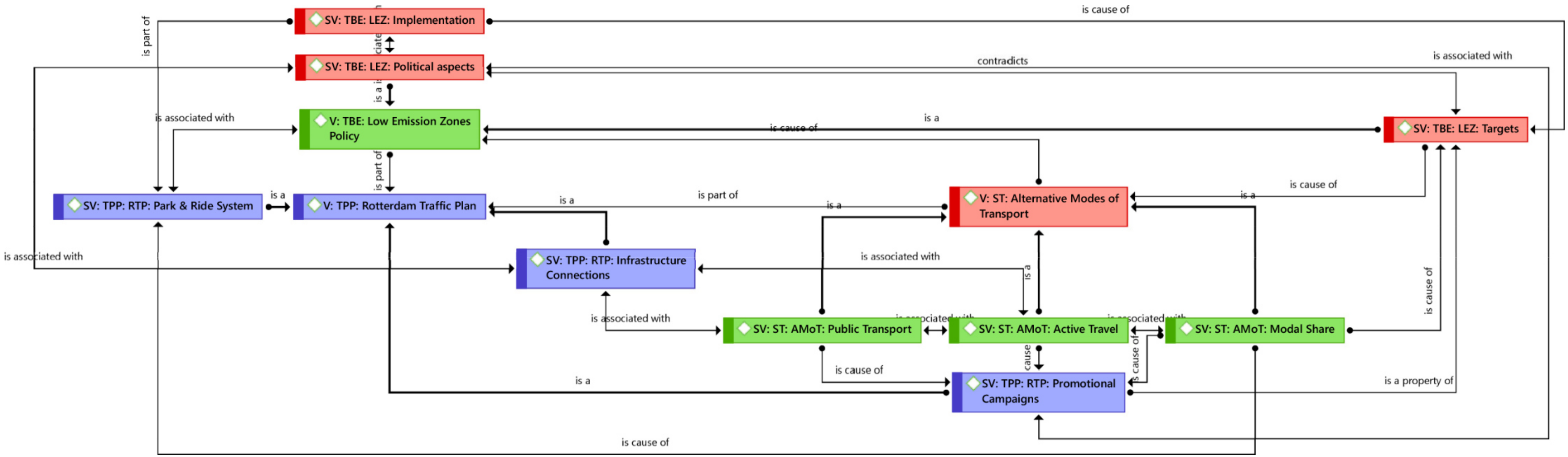
2. Cooccurrences tables

Table A2.2.: Frequency of intersection between all variables

		Alter. modes of transport			**LEZ policy**			**Rotterdam Traffic plan**		
		Active Travel Frequency=38	**Modal Share** Frequency=68	**Public Transport** Frequency=55	**Implementation** Frequency=63	**Political aspects** Frequency=42	**Targets** Frequency=165	**Infrastructure Connections** Frequency=60	P+R System Frequency=31	**Promotional Campaigns** Frequency=43
Alter. modes of transport	**Active Travel** Frequency=38	0	14	23	1	1	16	15	5	8
	Modal Share Frequency=68	14	0	18	9	4	43	24	8	5
	Public Transport Frequency=55	23	18	0	2	2	27	20	11	10
LEZ policy	**Implementation** Frequency=63	1	9	2	0	8	35	5	3	23
	Political aspects Frequency=42	1	4	2	8	0	29	2	1	1
	Targets Frequency=165	16	43	27	35	29	0	30	12	14
Rotterdam Traffic plan	**Infrastructure Connections** Frequency=60	15	24	20	5	2	30	0	9	7
	P+R **System** Frequency=31	5	8	11	4	1	12	9	0	2
	Promotional Campaigns Frequency=43	8	5	10	23	1	14	7	2	0

3. Variables/ sub-variables relationship network

Figure A2.1.: Relationship network



Annex 3: Different Datasets

1. Scrappage scheme extension request:

Toelichting
Sinds maart 2014 is de sloopsubsidieregeling van kracht voor de sloop van oude benzine- en dieselauto's, die na januari 2016 geen toegang meer hebben tot de milieuzone. Inmiddels zijn er in het kader van deze regeling ruim 5.100 voertuigen gesloopt. Medio 2017 is de looptijd van de slooregeling verlengd tot 31 december 2017 vanwege de instelling van een nieuwe subsidie regeling voor de ombouw van te oude voertuigen en de publiciteit rondom de rechtszaak inzake de milieuzone.

De regeling blijft ondanks het feit dat deze al enkele jaren loopt, nog steeds nieuwe aanvragen genereren, zo'n 5 per maand. Voor de verlenging van de slooregeling met een jaar tot 31 december 2018 is naar verwachting een budget van € 150.000 nodig.

Figure A3.1.: letter to city council about the results and extension of the scrappage scheme ('brf aan cie slooregeling').

2. Selected P+R metro stations for the comparison of in and out of the LEZ

Table A3.1.: Annual metro usage per different stations in Rotterdam (RET, 2020)

		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
IN	Beurs	49,339	51,566	56,827	53,852	60,739	57,460	61,070	65,065	58,568	30,862
	Blaak	10,598	11,823	11,773	11,696	12,967	13,130	13,575	14,022	15,267	9,556
	Blijdorp	1,329	1,411	1,779	1,709	1,863	1,975	2,165	2,182	2,593	1,646
	Coolhaven	7,835	8,041	7,871	7,778	8,340	8,239	8,167	7,715	7,641	4,438
	Delfshaven	4,884	5,165	4,735	4,562	4,744	4,602	4,962	5,220	5,434	3,713
	Dijkzigt	10,403	10,883	11,106	10,623	11,052	10,900	11,002	11,725	12,516	6,861
	Eendrachtsplein	5,113	5,536	5,218	5,148	5,182	5,106	5,713	6,575	6,489	4,551
	Gerdesiaweg	2,937	3,520	2,963	2,881	2,977	3,255	3,236	3,088	3,306	2,261
	Marconiplein	6,839	7,015	7,242	7,075	6,486	6,284	6,141	6,028	6,579	4,380
	Oostplein	4,706	5,413	4,443	4,263	4,253	4,934	4,905	4,886	5,362	3,482
	Rotterdam Centraal Station	19,800	19,133	19,278	19,188	22,332	21,131	23,115	24,546	27,722	16,232
	Stadhuis	5,689	6,103	5,402	4,772	5,484	5,137	5,595	4,415	7,610	4,418
	Voorschoterlaan	3,277	3,254	3,215	3,078	3,273	2,900	3,215	3,437	3,880	2,495
	Wilhelminaplein	9,807	10,449	9,676	9,115	10,978	11,000	11,303	12,616	14,678	8,606
Out	Alexander	8,678	8,461	7,795	7,497	7,714	7923	8376	8740	8267	4547
	Capelsebrug	9,179	9,344	8,739	8,521	8,854	8826	9311	9322	9870	6198
	De Terp	2,540	2,487	2,270	2,290	2,338	2308	2387	2356	2508	1669
	Kralingse Zoom	11,615	12,691	11,609	11,820	11,837	11665	12662	13084	13947	7842
	Meijersplein	902	968	1,412	1,509	1,813	1909	2095	2143	2587	1532
	Melanchthonweg	1,274	1,512	2,015	2,098	2,389	2610	2957	3028	3793	2206
	Nesselande	1,369	1,448	1,388	1,407	1,448	1454	1574	1601	1837	1097
	Pijnacker Centrum	1,196	1,398	1,460	1,346	1,400	1441	1609	1759	2022	1257
	Rodenrijs	1,251	830	2,232	2,356	2,625	2772	3002	3114	3313	1941
	Schenkel	2,350	2,386	2,344	2,290	2,311	2307	2335	2284	2406	1434
	Schiedam Centrum	10,074	10,440	11,038	11,023	11,180	11119	12021	13017	13433	8303
	Slinge	6,382	6,298	6,280	6,427	6,541	6782	7382	7885	8570	5586
	Slotlaan	1,160	1,129	1,048	1,033	1,172	1217	1269	1322	1429	905
	Zuidplein	18,089	18,707	17,283	16,787	17,667	17522	18454	19029	21203	13977

3. Selected P+R parking stations:

In: (Blaak, Blijdorp, Coolhaven, Eendrachtsplein, Gerdesiaweg, Marconiplein, Rotterdam Centraal Station, Stadhuis, Wilhelminaplein)

Out: (Alexander, Capelsebrug, Kralingse Zoom, Meijersplein, Melanchthonweg, Nesselande, Schenkel, Schiedam Centrum, Slinge)

Figure A3.2.: Example of the data received on the P+R parkin usage (Rotterdam, 2020)

			1998			1999			2000			2001		
gemeente	P+R - terrein	Capaciteit	Parkeervakken	Gem.bezetting	Bez.percentage	Parkeervakken	Gem.bezetting	Bez.percentage	Parkeervakken	Gem.bezetting	Bez.percentage	Parkeervakken	Gem.bezetting	Bez.percentage
Rotterdam	Centraal Station		90	77	86%	95	102	107%	110	106	96%	108	73	68%
	St. Franciscus		160	105	65%	99	92	92%	96	91	95%	96	79	82%
	Zuidplein	200												
	Wilgenplas	83	60	42	70%	60	54	89%	59	55	93%	49	52	106%
	Meijersplein	500												
	Alexander	478	473	484	102%	487	333	68%	544	563	103%	489	514	105%
	Kralingse Zoom	698	696	761	109%	711	747	105%	718	728	101%	703	738	105%
	Lombardijen	109	90	91	101%	90	92	102%	90	90	99%	89	93	104%
	Slinge	849	870	579	67%	816	373	46%	879	702	80%	826	413	50%
	Hoogvliet	226	300	238	79%	228	187	82%	234	216	92%	238	231	97%
	Hoogvliet Zalmplaat	60	36	11	29%	20	16	78%	36	10	28%	22	19	86%
	Hoogvliet Tussenwater	50								10				
	Pernis	33												
	Noorderhelling	322												
	Nesselande	46												
	Schenkel	102	101	99	98%	103	100	97%	102	94	92%	101	106	105%
	Capelsebrug	432	270	281	104%	444	388	87%	432	445	103%	463	455	98%
	Melanchtonweg	80												
	Hoek van Holland	82												
	Beverwaard	483												
totaal		*4150*	***2896***	***2585***	***89%***	***2959***	***2288***	***77%***	***3094***	***2911***	***94%***	***2980***	***2621***	***88%***

gemiddelden | 2017 | 2016 | 2015 | 2014 | 2013 | 2012 | 2011 | 2010 | 2009 | 2008 | 2007 | grafiek Rotterdam ...

Annex 4: SPSS results

1. Multiple comparison ANOVA for Research question 3:

Table A4.1.: Multiple ANOVA comparison

Multiple Comparisons

Dependent Variable: ALLPOINTS

Tukey HSD

(I) GROUPS	(J) GROUPS	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
ALLCARS	BIKES	101463.600*	3698.133	.000	89732.64	113194.56
	Metro	-75558.318*	3698.133	.000	-87289.28	-63827.36
	Tram	64167.710*	3698.133	.000	52436.75	75898.67
	Bus	93756.751*	3698.133	.000	82025.79	105487.71
	RINGCARS	79200.400*	3698.133	.000	67469.44	90931.36
	CENTERCARS	144906.800*	3698.133	.000	133175.84	156637.76
BIKES	ALLCARS	-101463.600*	3698.133	.000	-113194.56	-89732.64
	Metro	-177021.918*	3698.133	.000	-188752.88	-165290.96
	Tram	-37295.890*	3698.133	.000	-49026.85	-25564.93
	Bus	-7706.849	3698.133	.389	-19437.81	4024.11
	RINGCARS	-22263.200*	3698.133	.000	-33994.16	-10532.24
	CENTERCARS	43443.200*	3698.133	.000	31712.24	55174.16
Metro	ALLCARS	75558.318*	3698.133	.000	63827.36	87289.28
	BIKES	177021.918*	3698.133	.000	165290.96	188752.88
	Tram	139726.027*	3698.133	.000	127995.07	151456.99
	Bus	169315.068*	3698.133	.000	157584.11	181046.03
	RINGCARS	154758.718*	3698.133	.000	143027.76	166489.68
	CENTERCARS	220465.118*	3698.133	.000	208734.16	232196.08
Tram	ALLCARS	-64167.710*	3698.133	.000	-75898.67	-52436.75
	BIKES	37295.890*	3698.133	.000	25564.93	49026.85
	Metro	-139726.027*	3698.133	.000	-151456.99	-127995.07
	Bus	29589.041*	3698.133	.000	17858.08	41320.00
	RINGCARS	15032.690*	3698.133	.006	3301.73	26763.65
	CENTERCARS	80739.090*	3698.133	.000	69008.13	92470.05
Bus	ALLCARS	-93756.751*	3698.133	.000	-105487.71	-82025.79
	BIKES	7706.849	3698.133	.389	-4024.11	19437.81
	Metro	-169315.068*	3698.133	.000	-181046.03	-157584.11
	Tram	-29589.041*	3698.133	.000	-41320.00	-17858.08
	RINGCARS	-14556.351*	3698.133	.008	-26287.31	-2825.39
	CENTERCARS	51150.049*	3698.133	.000	39419.09	62881.01
RINGCARS	ALLCARS	-79200.400*	3698.133	.000	-90931.36	-67469.44
	BIKES	22263.200*	3698.133	.000	10532.24	33994.16
	Metro	-154758.718*	3698.133	.000	-166489.68	-143027.76
	Tram	-15032.690*	3698.133	.006	-26763.65	-3301.73
	Bus	14556.351*	3698.133	.008	2825.39	26287.31
	CENTERCARS	65706.400*	3698.133	.000	53975.44	77437.36
CENTERCARS	ALLCARS	-144906.800*	3698.133	.000	-156637.76	-133175.84
	BIKES	-43443.200*	3698.133	.000	-55174.16	-31712.24
	Metro	-220465.118*	3698.133	.000	-232196.08	-208734.16
	Tram	-80739.090*	3698.133	.000	-92470.05	-69008.13
	Bus	-51150.049*	3698.133	.000	-62881.01	-39419.09
	RINGCARS	-65706.400*	3698.133	.000	-77437.36	-53975.44

*. The mean difference is significant at the 0.05 level.

2. Multiple comparison ANOVA for research question 4:

Table A4.2.: Multiple ANOVA comparison

Multiple Comparisons						
Dependent Variable: Change_PR						
Tukey HSD						
(I) Group_PR	(J) Group_PR	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
METRO_IN	METRO_OUT	22935.750*	2288.066	.000	16142.71	29728.79
	PR_PARK	80344.571*	2288.066	.000	73551.53	87137.61
	PR_SPOT	79628.143*	2288.066	.000	72835.10	86421.19
METRO_OUT	METRO_IN	-22935.750*	2288.066	.000	-29728.79	-16142.71
	PR_PARK	57408.821*	2288.066	.000	50615.78	64201.86
	PR_SPOT	56692.393*	2288.066	.000	49899.35	63485.44
PR_PARK	METRO_IN	-80344.571*	2288.066	.000	-87137.61	-73551.53
	METRO_OUT	-57408.821*	2288.066	.000	-64201.86	-50615.78
	PR_SPOT	-716.429	2288.066	.989	-7509.47	6076.61
PR_SPOT	METRO_IN	-79628.143*	2288.066	.000	-86421.19	-72835.10
	METRO_OUT	-56692.393*	2288.066	.000	-63485.44	-49899.35
	PR_PARK	716.429	2288.066	.989	-6076.61	7509.47
*. The mean difference is significant at the 0.05 level.						

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